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[redacted] The purpose of the study is twofold: first, to provide a comprehensive survey of open Soviet literature relating to gyroscopic theory, applications, and equipment; and second, to provide an indication of Soviet accomplishments and capabilities in this field.

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Attachment A

AIR INTELLIGENCE INFORMATION REPORT

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A SUMMARIZED UTILIZATION OF THE NEW SOVIET LITERATURE IN THE FIELD OF GYROSCOPE THEORY AND TECHNOLOGY BASED ON PERSONAL EXPERIENCES IN THE SOVIET UNION

The arrangement of the following report deviates in some points from its original plan. This proved necessary because neither a report of personal experiences nor any published material could be obtained on some of the undoubtedly important topics included in the first draft.

In its essential points, however, the original outline for the arrangement of the report has been followed. The literature listed under Section IV is arranged according to the year of publication. Within the individual years, no special subdivisions have been made. Where literature listed in the index has been cited, the corresponding number has been included in the text in parenthesis.

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I. THEORY.

A. A Short Description of the Status in the Year 1945.

1. Treatises on General Gyroscope Theory.

After the various treatises by S. V. KOVALEVSKAYA on general gyroscope theory, i.e., on that part of analytical mechanics which treats the examination of the turns made by a rigid body around a fixed point, a large number of writings on this subject appeared in Russia during the years from 1890 to 1910. A few of the authors who contributed to this research work are as follows: V. A. STEKLOV, P. A. NEKRASOV, G. K. SUSLOV, N. E. ZHUKOVSKIY, G. G. APPELROT, A. M. LYAPUNOV, F. A. SLUDSKIY, B. K. MLODZEYEVSKIY, D. K. BOBYLEV, P. V. VORONETS, D. N. GORYACHEV, G. V. KOLOSOV, P. A. SHIF, and S. A. CHAPLYGIN. These have in part occupied themselves with this problem through decades and have brought forth many publications. Some of the results of this research work have meanwhile come to be included in the stock of the classic gyroscope theory as, for instance, the "BOBYLEV- STEKLOV Gyroscope", in which the moment of inertia around the principal axis, on which the center of gravity of the system rests, is twice as large as one of the other two principal moments of inertia, or the "GORYACHEV - CHAPLYGIN Gyroscope", which represents a certain specializing of the "KOVALEVSKAYA Gyroscope". Also remarkable is an analogy discovered by ZHUKOVSKIY between the equations of motion of an asymmetrical gyroscope and the equations of a vertically placed wire of oval cross-section, whose upper end is acted upon by a force and a moment. In addition to the contributions to research of S. V. KOVALEVSKAYA, another group of works must be included which, in part, follow those of POINCARE and LYAPUNOV, and which deal with the action of gyroscopes which are filled with liquid inside or which move in liquid. In addition to LYAPUNOV, there must be added to this group, S. A. CHAPLYGIN, V. A. STEKLOV, G. V. KOLOSOV and M. K. KURENSKIY. A good survey of these works of the best authors on Russian mechanics is to be found in the book by GERONIMUS (Section IV - Literature Index - No. 48), and also in the textbooks by SUSLOV (Section IV- Literature Index - No. 24) and NEKRASOV (Section IV - Literature Index - No. 19).

2. Treatises on Applied Gyroscope Theory.

The first Russian scientist who occupied himself with the question of applied gyroscopic movement was probably A. N. KRYLOV. Having early in his career examined the effect of gyroscopic force on the course of a rotating projectile, as well as on the action of elastic waves (a problem of the critical "number of revolutions" and of balancing), he later occupied himself intensively with the question of the gyro-compass. His textbook on gyroscope theory which he published jointly with Y. A. KRUTKOV (Section IV - No. 1) in 1932 is the first book of its kind in Russia.

As founders of the theoretical basis of Russian construction of gyroscopic equipment are to be regarded: D. G. TOPELBERT, A. N. KRYLOV, E. L. NIKOLAY and, above all, B. V. BULGAKOV. E. L. NIKOLAY, who was a professor of mechanics in LENINGRAD, enlarged on some of the research done by KRYLOV. A small monograph by him must especially be mentioned (Section IV, No. 18), in which he examines fundamental questions on the use of cardan suspensions for gyroscopes, and thereby calls attention to the important matter of friction around the individual axle bearings. Among other things he deserves merit for his books (Section IV, No. 28 and 31), which were published later and which served to popularize the gyroscope theory.

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In addition to some specialized treatises, the contributions of B. V. BULGAKOV include, above all, his textbook on "Applied Gyroscope Theory". Whereas KRYLOV limited himself chiefly to the problems of maritime technique (gyro compass and "Schlingerkreisel"), BULGAKOV treated the gyroscope theory from a more general angle, so that it could serve to examine the gyroscopic equipment used in aviation, which meanwhile had become known.

3. Treatises on the Theory of Individual Gyroscope Equipment.

KRYLOV, KUDREVICH and BULGAKOV occupied themselves with the theory on the gyro compass. This theory had been examined in such detail that, in conjunction with work done on this subject abroad, a fairly complete theory had matured by 1945. After TOPELBERT (Section IV - No. 39), it was the achievement of KUDREVICH that the practical application of the theory as well as the equipment itself were introduced into the Soviet Navy.

On the theory of the "Schlingerkreisel", examinations made by KRYLOV exist. He also tried to put his discoveries into practice. In his life's story he writes: "If the Ministry in Moscow had not refused to grant the 50,000 rubles which I would have needed to construct and to test a "Schlingerkreisel" on the yacht "Strela", we would now be in the lead in this matter and ahead of Sperry." Among the gyroscopic equipment for aviation, the horizontal gyroscope above all has been made the subject of theoretical research by various authors, including BULGAKOV (Section IV - Nos. 2 and 4), SHIPANOW and LEWENTAL (Section IV - Nos. 5 and 9). A paper by FRIEDLÄNDER treats the question of cardanic flaws in the directional gyroscope. Two publications (Section IV - Nos. 3 and 6) deal with the use of gyroscopic equipment for autopilots. From as much of this research as could be seen into, it was ascertained that it probably did not reach the status of the theory on this equipment which has been achieved, for example, in Germany (1945).

In summing up, it may be stated that by 1945 many papers on general gyroscope theory were at hand, some of which represented superior work, so that a certain degree of completeness already had been achieved in this field. Regarding applied gyroscope theory, research was still in an early stage; besides, the valuable treatises of BULGAKOW, some definitely inferior publications are to be found (for instance by CHIPANOW - Section IV - No. 5). What was published on gyroscope theory up to 1945 did not go beyond certain beginnings. In part, however, this may be due to the reservation observed during the war, specifically with regard to publications.

B. Survey of Treatises Which Appeared After 1945.

1. Treatises on General Gyroscope Theory.

As analytical mechanics are strongly furthered in the Soviet Union, it is not surprising that of late, also, numerous publications on the theory of general gyroscopic motions have appeared. In addition to the summarized presentation of the known standard results, for instance in Section IV, Nos. 24, 43, 44 and 48, we also find the attempt to verify the standard results with the aid of modern mathematics. The book by W. W. GOLUBOW (Section IV - No. 53) deals chiefly with the KOWALEWSKAYA case of gyroscope motion.

Some individual works of research are to be named which tie in with and, in part, enlarge on standard results. They are: (a) examinations made by KUSMIN (Section IV - No. 50), who by means of a special attachment for

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the gravity moment succeeded in treating the STEKLOW gyroscope with JACOBI's elliptical functions; (b) the work of SRETENSKI (Section IV, No. 59), who examined the movement of the GORJACHEW - CHAPLYGIN gyroscope for eventual special cases in which a great initial impulse exists around the main inertial axis which passes through the center of gravity. By this procedure, he attained an analogon to the pseudo-regular precession of the LaGrange gyroscope. (c) Research by MERKALOW (Section IV - No. 27) on the KOWALEWSKI gyroscope. MERZALOW did not limit himself to theory but carried out practical experiments, photographing the movement of the gyro axis. It is an interesting fact that he thereby saw certain possibilities for the practical use of the KOWALEWSKI gyroscope. The fact that the movements of the KOWALEWSKI gyroscope are not periodic is the very thing which might prove favorable for some uses, for instance, for sliding (In German: "beim Schleifen"); (d) CHETAYEW (Section IV - No. 62) gives a new derivation of the stability requirement of the LaGrange gyroscope when the direct method is used, whereas (e) RUMJANZEW (Section IV - No. 63) used the same procedure with the derivation of the stability requirement for the KOWALEWSKI gyroscope.

Regarding the theory of the movement of a gyroscope in liquid, three treatises became well established. Two of them (Section IV - Nos. 66 and 67) tie in with the standard classical cases and examine special problems in point of the movement of a gyroscope in an ideal, incompressible liquid. RUMJANZEW does not limit himself thereby to the examination of rotations around a fixed point; but also takes stationary screw movements into consideration. A paper by KOSHLJAKOW (Section IV - No. 56) may have been primarily the result of answers to practical questions posed. He examines the action of gyroscopes in a non-ideal liquid, making certain assumptions regarding the moments which the liquid produces on the gyroscope. In special cases, one can even obtain rigid solutions to the Euler-equations.

RUMJANZEW also occupied himself with a further problem - the action of a gyroscope having hollow spaces filled with liquid (Section IV - Nos. 64 and 65). Enlarging upon the results obtained by JUKOWSKIY, he now also takes into consideration a free surface for the liquid for the otherwise assumed ideal and incompressible fluid located within the hollow spaces. The author contents himself with the setting up of equations of motion and with some related, general remarks on possible first integrals of these equations. Solutions or attempts at solutions are not given.

2. Treatises on Applied Gyroscope Theory.

When one considers the flood of new books which have appeared in the years since the war (1945), it is astonishing that no book on applied gyroscope theory has been published which even approaches the earlier books of KRYLOW and BULGAKOW. Only a monograph by OKUNJEW (Section IV - No. 45) can be named, which is long, but, in point of subject matter very narrowly limited. Obviously it began as research in ballistics, although this is not exactly stated anywhere. However, the presentation of the problems and also the examination methods are completely adjusted to gyroscopic problems as they appear in the field of ballistics. Thus the small oscillations of symmetrical gyroscopes are examined in detail when damping couples of various types appear (axial or equatorial, or both simultaneously), and much care is spent in discussing the trajectory of the gyroscope tip (projectile tip) under various starting conditions. A more generalized treatise by FRIEDLÄNDER (Section IV - No. 52) is neither especially significant nor convincing in the manner of its execution. Regarding the so-called pseudo-regular precession, he attempts to compute not

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only the shape of the curve (as function of time) of the position of one of the main inertial axes, but also the non-visible instantaneous axis of rotation and the likewise non-visible impulse axis.

Some studies dealing with the question of the effect of cardanic bearings on the behavior of a gyroscope has proved to be of value for the theory on gyroscopic devices. The first to be named in this connection is NICOLAY who, in supplementation of an earlier monograph (Section IV - No. 18), in his textbook on gyroscope theory (Section IV - No. 31), also derives the motion equations for gyroscopes with cardanic bearings, without neglecting the mass of the cardan rings. Application of these equations, however, are not made. In the same book, NIKOLAY names expedients which can be used in connection with a theory on gyroscopic devices in mobile reference systems, by deriving the general equations for the motion of a gyroscope in reference systems, with motion according to choice, (generalized Euler equations). In addition, research work was done by SLOMJANSKIY (Section IV - No. 58) on symmetric gyroscopes with cardanic bearings. He dispensed with a linearization of the motion equation, but nevertheless neglected the masses of the cardan rings. In this manner he examined, above all, the regular precession, as dependent upon the current reciprocal position of the two cardan rings.

A treatise by METELITSIN (Section IV - No. 51), short but rich in content, is of great significance for the theory and outlining of gyroscopic systems. Here the author succeeds in clarifying the influence of the various types of power which are effective in a dynamic system (dissipative, gyroscopic, conservative and actually inconservative powers) on the stability requirements. In this manner, he arrives at some very general statements on the possibility or impossibility of stabilizing dynamic systems by the addition of gyroscopes. It will be possible to put these statements to very good use, especially in designing complicated gyroscope systems.

New viewpoints on the problem of acceleration-free adjustment of gyroscopic devices were brought to light by a brief examination made by TKACHEV. Whereas previously the 84-minute principle had been limited to only such devices in which the gyroscope in some way was subject to gravitational anchorage, thus representing a kind of gyroscopic pendulum, TKACHEV now showed that systems without gravitational anchorage also possess a natural oscillation duration of 84 minutes in cases of acceleration-free adjustment (German: "Abstimmung"). The paper does not treat the practical application of this discovery.

3. Treatises on the Theory of Individual Gyroscope Equipment.

Of the many books which deal either entirely or in part with gyroscopic devices and their related theories, unfortunately only two were available: PAVLOV (Section IV - No 22) and TOPELBERT (Section IV - No. 39). On the point of gyroscope theory, these two books offer only certain elementary basic information. Of greater importance, on the other hand, are two other books which were available in the Soviet Union. SOLOWJEV (Section IV - No. 33) does not offer anything new on the theory either, but because of the large amount of material he has gathered, and because of the data on Soviet devices, his book is very valuable. KOZLOV (Section IV - No. 37) has explained in detail the question of the support of gyroscopic horizons and of directional gyros and thereto tenders a theory not previously found in such detail. It is unfortunate that the comprehensive report of ROYTENBERG (Section IV - No. 42)

was not available, as this would probably be of the greatest importance in the judging of these gyroscopes. The newer book by PAVLOV (Section IV - No. 60) also could be very informative, although it is to be expected that its significance will be more in the practical realm.

TOPELBERT (Section IV - No. 59) treats the theory of the gyro-compass in detail in his book of about 100 pages. The author himself adds nothing new to this topic, but uses the numerous papers previously written on this topic by KRYLOW and BULGAKOV as a base. It is striking that in all Russian compass theories there is a predelAction for those questions which deal with the 84-minute-setting ("Abstimmung"). The most interesting paper on the subject of the gyro compass is undoubtedly an early publication of BULGAKOV (Section IV - No. 14) in which, with the aid of an operator's method, the most dangerous maneuver for the course indication of a ship and the accompanying acceleration error of the compass indicator is computed.

The theory of the artificial horizon, the development of which already had been well advanced by the research of BULGAKOW (Section IV - Nos. 2, 4 and 8) has been given relatively little attention since 1945. KOSHLJAKOV (Section IV - No. 41) examines the indication errors of an artificial horizon for cases in which the rotation speed of the rotor is subject to certain changes, whereby either momentary slight changes of the otherwise constant number of rotations or slight periodic variations are assumed. In both cases, he comes to the conclusion that the influence of the variation in the number of rotations on the indicator may be overlooked, provided that the variations themselves remain slight. In a later work (Section IV - No. 56), he again takes up the same problem; he computes the indicator error for the case that the gyroscope drive is suddenly completely cut off. For some arbitrarily assumed time functions of the rotation speed course, he finds corresponding damped "error motions" ("Fehlbewegungen") of the gyroscope axis.

Research done by DANILIN (Section IV - No. 46) represents a very interesting case. The writer already had been able to examine this work in the Soviet Union and had ascertained that, in part, it had been copied verbatim from a paper which had been published nine years previously in the German periodical "Luftfahrtforschung" (Vol. 19, 1940, pages 23-43), and that the illustrations, in part, simply had been taken over as they were. The original German work, however, had not been cited. A letter of complaint to the editor of the periodical "Automatika i Telemekhanika", accompanied by a special print of the German article as proof, was never answered. Some years later it was ascertained by chance, that the work of DANILIN was not included in part of the edition, although the title and the numbers of the pages were included in the index of all the issues for that year.

On the theory of the turn indicator, there is knowledge of only one paper, by PALPOR (Section IV - No. 25) which, unfortunately, was not available.

An interesting new type of gyroscopic device has been calculated by KHOKHLOV (Section IV - No. 29). He calls it gyroscope-magnet and tries thereby to establish a direct connection between an astatic gyroscope and a magnetic needle, in contrast to the usual connection of the two pieces of equipment by means of a slowly functioning correction mechanism ("Korrektureinrichtung"). Interesting though these examinations are, they are too theoretical to be put into practice. Although it is possible to solve the motion equations of the system by making use of some daring aids, yet the result can scarcely be used in a practical sense. The period of oscillation of

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the equipment, for instance, should be adjusted at the equator to 12 hours (!) and, at a latitude of 60° to even double that value.

Two papers deal with problems of gyroscopic stabilization: ROYTENBERG (Section IV - No. 30) examines the self-exciting oscillations of a stabilized platform whose motions are measured by a gyroscope and influenced by a supporting motor. Because of a certain insensitive zone and a black-white characteristic of the steering potentiometer of the gyroscope, stationary self-oscillations are possible, whose frequency, amplitude and stability are computed. From the figures given in the example shown, it is easy to gather that the purpose of this research is to clarify the behavior of heavy, stabilized platforms (artillery on ships ?). In this work, incidentally, attention is directed to a not yet published work by A. I. LURE , which also deals with the behavior or a gyroscope equipped with a support mechanism.

BAUTIN (Section IV - No. 36), in his interesting monograph, also treats of gyroscopic stabilization: a mono-rail train and also a gyro-stabilized ship. The two problems are similar, differing from each other only in that, in the case of the mono-rail train, the center of gravity of the gyroscopic system lies <u>over</u> the lowest point of support, whereas in the case of the marine stabilizer it must lie <u>under</u> it. BAUTIN searches for the limit of stability and comes to the conclusion that in the case of the marine stabilizer the limit of stability is always safe, whereas in the case of the single-track train dangerous limits of stability may occur.

II. DEVELOPMENT AND PRODUCTION.

The number of descriptive publications is slight compared with the number of the works on theory hitherto discussed. Hence, few treatises are available on the basis of which to judge the practical problems of production and development of gyroscopic equipment. Most of these are found in books which were published a few years after the end of the war, and therefore probably represent the status toward the end of the war. (1945). It would be well to keep this in mind in judging the following presentations.

A. Gyroscope Equipment.

1. Directional Gyroscopes.

The first directional gyros used in the Soviet Union came from firms abroad (principally Sperry-Askania and Siemens). At first, this equipment was put to use just as it came; later, efforts were made to improve on the precision of the equipment by means of more refined regulating in point of standard values. This proved to be especially necessary during flights in arctic regions. In the book of SPIRIN (Section IV - No. 11), there is a notation on this subject. However, it is not possible to ascertain from this quotation what details comprised this regulating or what results were achieved.

Beginning with the year 1934, the construction of the foreign equipment was at first copied exactly. Later changes were made in individual parts. Illustration No. 1 ([redacted]) is a view of one of the first directional gyros built in the Soviet Union (after OLMAN - Section IV - No. 23). The support here is pneumatic over a rough spherical calotte, against which single air jets are blown. The air jets are steered by a magnetic telecompass. The correction speed equals 6 - 8° per minute. When curves are to be flown with this equipment a precession speed of 50-60° per minute is

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attained by blowing with a strong air jet. Thus, while the curve is being flown, the gyroscope retains its axial direction relative to the curve-flying aircraft. An aircraft steered with this directional gyro is said to hold its course with $\pm 2^{\circ}$ precision.

In later types of autopilots, there was a changeover to the Sperry constructions, which were of proved quality, or to copies of the Sperry constructions by Askania. Whereas changes were made in the steering gear, for instance in the steering engines, in order to adjust the permissible temperature range of the autopilot to the conditions prevalent in the Soviet Union (-50° C to 60°C), the directional gyro in the autopilot СТЛ - 4 and АВП -12 has been left unchanged. In the autopilot, АП - 42, however, which is more highly developed, a change has been made in the locking device as is shown in Illustration 2 (see original German [illegible] In place of the formerly used azimuthal cog wheel into which, in order to pre-set the course, an adjustable pinion could be inserted, a construction now has been chosen which obviously has been borrowed from the Siemens directional gyro. A disc, 2, which is movable in an up and down direction, has a circle of holes at its periphery into which two small pins can catch, which are not visible on the illustration. The mechanism simultaneously makes pre-setting and locking possible as the disc, 2, when it rises, takes the catch ("Arretierhebel") with it, which, in its final position, firmly holds the inner cardan ring in such a way that the gyroscope axis assumes a horizontal position. The support mechanism also has been changed. In place of the pneumatic support, a magnetic support is being used, which also has been taken over from the Siemens construction. The inner cardan frame bears two small permanent magnets, one of which (4) is visible in Illustration No. 2. In the upper part of the casing (Illustration No. 3 - see appendix page [illegible]) there is a coil which, if the gyro axis deviates from the correct value ("Sollwert"), is changed by a current, and, in this manner, effects a correction moment on the gyroscope. At the time the book was being written (Section IV - No. 23), this equipment represented the most modern Soviet directional gyro which was being used in autopilots.

In addition, efforts were made in other places for the further development of the directional gyro. This can be seen from a table contained in the book by PAVLOV (Section IV - No. 22) which, significantly, is not accompanied by any text.

In addition to the directional gyro by ANSCHUETZ and the "static compass" of the firm of BROWN, three pieces of equipment are presented here which, presumably, are of Soviet origin, or at least were copied in the Soviet Union. They are characterized by the following data:

	Accuracy Deg/hour	No. of Rotations 1/min	Impulse (g cm sec)	Frictional Moment (g cm)	
				Horizontal	Vertical
Simple directional gyro of low capacity	$10 - 15^{\circ}$	18,000	9821	1,22	4.0
Directional precision gyroscope	2°	18,000	129,896	5-6	7.8

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	Accuracy Deg/Hour	No. of Rotations 1/min	Impulse (g cm sec)	Frictional Moment (g cm)	
				Horizontal	Vertical
Modernized directional gyroscope of low capacity	3°	18,000	12,252	1.2	2-3

From the given data on impulse and number of rotations, it is easy to ascertain that the two directional gyros of "low capacity" belong to the type which has the dimensions usual in aviation. The "directional precision gyroscope", however, is considerably larger; its rotor possibly weighs 3 kilograms.

2. Horizontal and Vertical Gyroscopes.

Illustration No. 4 (see appendix ... shows a diagram of one of the first horizontal gyroscopes built in the Soviet Union. At this stage it does not as yet function as a horizon indicating piece of equipment, but works jointly with the speed-measuring Venturi tube in the automatic longitudinal stabilization of an aircraft. The gyroscope is steered through the Venturi tube over the illustrated pneumatic support mechanism and renders an oscillation-free direction indication for the steering of the longitudinal motion. Illustration No. 5 (see appendix, page 3 ... shows the construction process of the gyroscope.

Later models of autopilots (Type СТЛ-4) were made into independent equipment by the installation of two supporting pendulums. Illustration No. 6 (see appendix, page 3 ... shows the diagram of this horizon. The steering pendulums 1 and 2 have short natural oscillation periods ("kleine Eigenschwingungszeiten"), and hence adjust themselves with very little deceleration to the "Scheinlotrichtung" (imaginary vertical reference). Both pendulums have a pair of nozzles each, through which air is blown against the spherical rough shell which is attached to the inner cardan ring. The blower nozzles are partly closed by a shutter (3), which is firmly connected with the outer cardan ring. A shutter formed especially to suit this purpose causes the outer cardan ring always to precede vertically in the direction of the "Scheinlot" (imaginary reference).

The automatic radio compass of the type (АП-42), according to reference book 25 (Section IV of this report), the most modern one, has a horizon which, remarkably, deviates in many points from the well known Sperry horizon. (See Illustration No. 7 - appendix, page 3 ... Unlike the Sperry, the axis of the outer cardan ring does not lie in the direction of the longitudinal axis of the aircraft, but lies vertically to it. Although this makes for a simpler indication of the longitudinal and lateral reference, the degrees of freedom ("Freiheitsgrade") of the equipment are consequently somewhat less favorably distributed. They are +80 and -35° for the longitudinal inclination, and ±55° for the lateral. The mechanism is so installed that the gyroscope axis is not stabilized exactly in the imaginary vertical reference plane, but is stabilized somewhat inclined in the flight direction. Further differences, as compared to the Sperry horizon, exist in the form of the support pendulum and in the type of the "pickoff", which here is done by a pin sliding in a groove. The mechanism is stated to be capable of working in a temperature range of -35°C to +60°C. No mention is made of the indication accuracy of the equipment.

Independently of these horizons used in the automatic radio compasses, another horizon was designed by BULGAKOV and ROYTENBERG (see Section IV - No. 34), to which the treatise by TKACHEV (Section IV - No. 38) also refers. No details on this horizon are known as the original paper was not available. Nor is it possible to ascertain whether the equipment was tested, or whether it was constructed in quantity. In the available papers, nothing is said on vertical horizons. The only work, the title of which refers to them (see Section IV - No. 26 - ROYTENBERG), could not be obtained.

3. Turn Indicator and Accelerometer.

In the autopilots used in the Soviet Union, no turn indicators or accelerometers were used at least until 1946. The book (Section IV - No. 23) contains only a short description of the turn indicators used in the German autopilots by Askania and Siemens, and a likewise short description of the "Vorhaltkreisel" (lead gyroscope) in Type LZ-14 of the Askania steering gear. Even in the otherwise very detailed book by PAVLOV (Section IV - No. 22) gyroscopes for measuring rotational speed are mentioned only once, and at that very briefly. As, except for this, only a single publication on this topic can be found (Section IV - No. 25), there is reason to assume that in the Soviet Union no importance was attached to the turn indicator.

4. Measuring Gyros.

In one place, PAVLOV (Section IV - No. 22) mentions two gyroscopes used for measuring. One has full cardanic bearings with three degrees of freedom; the rotations of the outer cardan ring are measured, i.e., recorded, with reference to the casing. Thus, according to the sketch, it is a case of a simple measuring mechanism for the angle of rotation. The second gyroscope has an elastic suspension of two degrees of freedom, in which the deflection of the gyroscope frame is proportionate to the rotational speed. PAVLOV, however, designates both mechanisms as "accellerographs", i.e., as accelerometers.

5. Stabilizing Gyros.

Gyroscopic stabilization is publicized only in literature pertaining to the Soviet Navy. In addition to the already mentioned research on ship gyroscopes by BAUTIN (Section IV - No. 36), the work done by ROYTENBERG (section IV - No. 30), which dealt with the stabilizing of larger platforms, should be mentioned above all. Obviously self-oscillations had been observed in such platforms, and the research done by ROYTENBERG was to serve to clarify their theory. As can be gathered from the report, according to this system the outer cardan ring of a gyroscope is firmly connected with the platform to be stabilized. In case of interference for the platform by rotational moments, the gyroscope precedes around the axis of the inner cardan ring and thereby activates a contact system, i.e., a potentiometer. Thereby, over an amplifying device, a motor is switched on, which counteracts the interference moments. The weight of the stabilized platform lies between 0.5 and 1 ton (metric); the gyroscope weighs about 20 kilograms. The stabilizing motor has a rated current of 6 amp., and thereby supplies a stabilizing moment of 45 mkg.

In his book, PAVLOV (Section IV - No. 22) describes an older construction of the stabilization gyroscope by SHILOVSKIY, which is to serve for the stabilization of the target mechanism of ship artillery. In this case, the sighting telescope is firmly connected with the gyroscopic axis. Directional changes of the telescope occur as the effect of corresponding precession

moments as caused by the observer.

6. Other Gyroscopic Equipment.

TOPELBERT (Section IV - No. 39) describes a gyroscopic sextant which was introduced into the Soviet Navy. On the sextant casing, there is a small gyroscopic horizon which, in principle, does not differ from the well-known construction of FLEURIAIS. The rotor weighs about 200 grams and its rotation amounts to about 10,000 rpm by being blown at by an air jet. In order to start it, the horizon with its casing is taken off the sextant and later put on again. The measuring itself is done when the gyroscope is decelerating. It should be noted that the time available for measuring amounts to about 5 to 6 minutes; after this time the rotation of the gyroscope has diminished to such an extent that the accuracy of the equipment no longer suffices. Oscillations of slight amplitude scarcely influence the using of the equipment because of the conical bearings selected for the gyroscope suspension. According to experience, 120 seconds of self-oscillation result in the most exact indications and the least influence on the ship's movements. In calm weather, the accuracy is given as from 2 to 5 "Bogenminuten" (curve or arc-minutes).

TOPELBERT also makes statements on gyroscopic equipment for the direct indication of the geographic latitude. It is known that the gyration compass and the gyroscopic horizon both have indication flaws, which relate to the geographic latitude. Thus the geographic latitude could be determined by measuring the flaw. A discussion of the measuring accuracies required for this purpose, however, shows that usable results could scarcely be attained in this way. TOPELBERT therefore brings up a thought which refers back to FOUCAULD, according to which a gyroscope with two degrees of freedom executes undamped oscillations around the direction of the earth's rotational axis, if it is allowed to participate in the earth's rotation in a suitable way. It is stressed, however, that the problem of constructing a piece of equipment on this principle, and usable for navigation is not yet solved. So far, the required accuracy for navigation has not been attainable.

The "gyro-magnet" mentioned in research done by KHOKHLOV (Section IV - No. 29), which is to serve to indicate the course, and which pre-presents a new type of combination of directional gyro and magnetic needle, has not yet been built.

SHLANDIN (Section IV - No. 47) mentions a "gyro-induction-compass" which has 3 inductive leads which respond to the magnetic feel of the earth and are mounted on a gyroscopic casing in such a way that they lie in a horizontal plane. Thus oscillations of the lead are avoided and the so greatly feared "north turning error" can be considerably reduced. The accuracy of the induction measuring is stated to be $\pm 2^{\circ}$. Construction details on this gyroscope are not given. This gyro-induction-compass is also used in a combination equipment ("Auto Navigator"), by means of which, using the measured quantity of the course, speed, wind direction and wind speed, the flight course is computed and immediately recorded on a card.

B. Individual Parts of Gyroscopic Equipment.

1. Rotors.

After a discussion of the construction details of various exclusively foreign rotors, PAVLOV (Section IV - No. 22) presents a table in

which he has compiled data on the characteristics of 14 rotors. In nine cases, the foreign firm which produced the rotor is stated (ANSCHUETZ, BROWN, SPERRY); in the other five cases, there is only a dash in the corresponding space and column, so that it may safely be assumed that these rotors are of Soviet origin. Here are the data on these rotors:

P (g)	θ (gcmsec)	n (1/min)	D_m (mm)	D (mm)	H (mm)	h (mm)	d (mm)
714.6	5.21	18000	98	72	66	10	35.4
788	6.5	18000	100	75	55	8	35.4
2878	71.44	18000	160	136	68	4	56
3261	70.98	18000	168	124	70	5	56
2900	68.90	18000	168	124	70	5	56

Symbols: P = weight of the rotor.

θ = inertia moment around the axis of rotation

n = number of rotations

The other characteristics are the geometrical measurements of the rotors as shown in Illustration No. 8. (See appendix page [illegible]). All five of the rotors given in the table belong to Type F. This indicates that it was planned to apply the lessons learned during the copying of the ANSCHUETZ-compass-rotors to the construction of Soviet gyroscopes.

No deviation took place from the basic construction of the rotor disc of equal rigidity on an elastic shaft, only minimum changes in the size were undertaken. The weights and inertial moments are somewhat increased, the number of rotations is somewhat less than in the ANSCHUETZ equipment, the impulse is only slightly greater. It is interesting to note that now the same type of construction has been followed for the two smaller rotor types also (the two first ones in the table). Of the other rotor types noted in Illustration No. 8, under symbols , no Soviet constructions have been mentioned.

For use in gyro-compasses, two other rotors were constructed in the Soviet Union, whose form is shown in Illustration No. 9. (See appendix page [illegible]. These rotors weigh 23 Kgs and 10 Kgs respectively; their outside diameters are 250 and 150 mm. Their RPM are 6,000 and 10,000. Their activation is through three-phase polyphase current of 45-volt voltage. The low revolution rotors are made of manganese bronze and run in air under normal pressure; on the other hand, the faster rotors are made of steel and run in a vacuum (?). (NOTE: Question mark made by MAGNUS). Illustration No. 10 (see appendix page [illegible]) is a view of such a rotor in its casing.

In addition to the alternating current rotors treated up to now, a small direct current rotor also has been developed by B. A. TALALAI in the Central Aero- and Hydro-dynamic Institute TsAGI. However, nothing is

known about it in detail. The only mention made (Section IV - No. 23) is that serious difficulties occur because the mechanism includes a collector.

The pneumatically-driven rotors are obviously only copies of the well-known constructions of Sperry or Askania. There are both types of equipment, those which work at high pressure and those driven by low pressure. For the drive itself, two variants are employed. In the one, the propulsion nozzle is mounted inside the gyroscope casing, i.e., in the inner cardan ring (for instance, in gyroscope horizons); in the second case, the propulsion nozzles are connected with the outer ring (as in the directional gyro).

2. Bearings.

PAVLOV (Section IV - No. 22) covers about 40 pages in treating the question of rotor bearings in detail. Not only are data given about the requirements of rotor bearings during various motions of the casing, but also details for conducting calculations for the bearings. Among other things, many numerical values of Soviet constructions are given. Illustration No. 11 (see [illegible]) shows the four main types of bearings chiefly used in the Soviet Union. Type A shows the bearings put out by the firm "NORMA" which are usually used in the Sperry mechanisms. In copying these mechanisms, bearings of Type [illegible] were used in place of those of the "NORMA" Company, which differ from Type [illegible] mainly only in the form of the bearing surfaces at the tip. According to No. 23, Section IV, bearings of Type C are being very frequently used of late. Type [illegible] has the advantage, in that bearings of this type can be obtained in series from the ball bearing factories. These ball bearings, also called "magnet bearings", have been included in the norms and are manufactured by the factory ГПЗ under numbers: 6006, 6008, and 6010. The last digits of the [illegible] ("Kennzahlen") indicate the inner diameter in millimeters. The outer diameters of the bearings are 21, 24 and 28 mm, respectively. The axial play is indicated to amount to a value of .005 mm. The friction values of the bearing race lie between 5 and 8 g cm. The quality of bearings is generally measured on the basis of the time required for starting and stopping the motion. The statements made on this subject by PAVLOV in his book fail in this respect, since he does not separate bearing friction values from those of air friction.

The reference book (Section IV - No. 55) contains very detailed information on all types of Soviet ball bearings. The various types of ball-bearings for all purposes are listed here, using the Soviet norms and giving all data.

As the question of bearing-friction in the cardan bearings of gyroscopic equipment is of decisive importance for indicator-accuracy, PAVLOV (Section IV - No. 23) treats it in considerable detail. Although he analyzes the various types of bearings in foreign equipment, his descriptions do not show which of the types of bearings discussed are being used in the Soviet Union. One learns only that in some of the mechanisms for autopilots (automatic radio compass), ball-less conical bearings also were used, but that these did not prove satisfactory because of the high demands made on the contact surfaces. Oscillatory bearings ("Schwinglager") of domestic construction are not mentioned at all in Soviet writings. The fact, however, that foreign constructions of this type are discussed in great detail, leads to the conclusion that this type of bearing has been tested and possibly even constructed in the Soviet Union. These suppositions are supported by two things; first, KRASOVSKIY (Section IV - No. 35) in a publication brings a theory on oscillating bearings and

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thereby expressly points to their use in the construction of gyroscopic equipment. He also gives the results of experiments. Secondly, the construction of a special ball bearing became known, having three rings and two bearing races (Section IV - No. 33), which is especially planned for the construction of low friction oscillatory bearings ("Schwinglagerungen").

None of the available publications contained anything on the very timely questions of pneumatic, hydraulic, electrical, magnetic or electromagnetic bearings of gyroscope systems. However, TOPELBERT does mention the problems which arise in the suspension of compass systems. In the Russian gyrocompasses, a thread suspension has been used to relieve the supporting ball bearings, by which the weight of the system is taken up. The ball bearings then function only as guide bearings ("Fuehrungslager"). In order to avoid interference torques due to the twisting of the thread, a compensating rotational device ("Nachdreheinrichtung") has been installed. Although the floating suspension of the compass ball ("Kompasskugel") used in the two-gyro compass of ANSCHUETZ is described, it does not seem to have been taken over into their own (i.e, Soviet) construction.

3. Pickoff Points.

It is remarkable that in the publications about the various gyroscopic mechanisms and individual parts, with the help of which the indicator values of the gyroscopes are converted into, for instance, electrical values, nothing can be found about pickoff points. These questions, however, are treated in considerable detail in the more general new publications (Section IV - No. 47) (Section IV - No. 54), both of which have the character of reference works. Principles, modes of execution, and papers of computation for the most important of the selsyn types (GEBER) (resistance, inductive, capacitative and photoelectrical) are discussed, without any mention of the individual use of these selsyns in gyroscopic mechanisms. Only in the discussion on resistance wire potentiometers is it stated that, in sensitive aeronautical equipment, in which it is of vital importance to have as little friction as possible, special resistance selsyns should be used, wound of very thin (0.03 mm) platinum-iridium wire. The resistance of these selsyns mounts up to 5 ; the good corrosion resisting qualities of the wire permit the use of "Schleifern" (contact strips) with a contact pressure of "several tens of milligrams". The contacts themselves are so light that even if higher accelerations should occur, there would be no danger of basing contact.

4. Supporting Mechanisms.

The supporting mechanisms mentioned in the publications do not differ greatly from the known types of foreign gyroscopic equipment. Some of the mechanisms may be seen in part in the illustrations of earlier paragraphs the well-known though constructionally somewhat changed air bearing ("Luftstuetzung") for a gyroscope horizon in Illustration No. 7 (see appendix page 3), or the supporting mechanism of a directional gyro (Illustrations No. 2 and 3 - see appendix, page 1 and [illegible]), which consist of two small permanent magnets on the inner cardan ring and a spool through which current flows, in a casing, and through which the directional gyro is adjusted according to the indications of the magnetic telecompass ("Magnetfernkompass"). Finally, Illustrations No. 1, 4 and 5 (see appendix, pages [illegible]), show a pneumatic support mechanism, in which the correctional moments are produced by blowing air at a rough half spherical shell ("rauhe Halbkugelschale").

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In the supporting mechanisms, it is possible to distinguish between indicators and selsyn moments ("Momentgeber"). PAWLOW (Section IV - No. 22) treats several of the more usual indicators, for instance, leveling selsyns ("Libellengeber"), which either have a ball rolling in a curved glass rod or consist of a U-shaped rod filled with quicksilver. In point of the selsyn moments, only electrical or electro-magnetic mechanisms are taken under discussion. For a rotary magnet with a Z-shaped armature, which is obviously of Soviet origin, the moments are stated to be a function of the angle of rotation. It is to be seen thereby that this construction is usable up to angles of about 70°. Other constructions may require a lower performance, but they also have an appreciably inferior rotation angle characteristic.

Special papers on the various types of selsyn moments may also be found in Section IV - No. 54.

5. Locking Devices.

The directional gyro shown in Illustration No. 1 (appendix ...), as well as the horizon shown on Illustration No. 5 (original German text - Pg. 18) possess a locking device which deviates from the other known devices of its kind. The principle on which they are based can be seen from Illustration No. 12 (see appendix page 5). A rotatable bar is attached to the casing of the equipment, which can be set in motion over a cranking mechanism by means of a small air-pressure cylinder. If there is no air-pressure in the cylinder, then the spring (15) pushes the piston upwards, thereby turning the lever (10) in such a manner that the two ends (17) touch and run upon two V-shaped tracks on the outer cardan ring and, in the final position, simultaneously fix both cardan rings. Now, if a pressure of from two to three atmospheres is let into the cylinder, the lever (10) turns back and releases the mechanism for work. In Illustrations No. 1 and 5 ..., the individual parts of this device are plainly to be seen.

Another locking device has already been mentioned in Section II-A-1 and shown in Illustration No. 2 ([redacted]). It is a question of a change in the locking device of the Sperry directional gyro after the model of the Siemens directional gyro. PAWLOW (Section IV - No. 22) deals with the various kinds of locking devices in considerable detail, weighing their advantages and disadvantages against each other. He describes the device shown in Illustration No. 13 (see appendix page 5) as one of the latest constructions of this type.

By turning the handle (6), two levers (15), which have rollers at their ends, are swung upwards, and the gyroscope casing is locked opposite the cardan ring. By depressing the button (7), the cardan ring is held fast and can be set in the desired position by turning this same button. For simpler cases, PAWLOW recommends the use of the locking device shown in Illustration No. 14 (see appendix page 5) which, however, has this disadvantage, i.e., that the gyroscope axis can be held stationary only in a single position.

Constructional details on individual locking devices can also be found in the reference work (Section IV - No. 55).

6. Other Individual Parts.

The various types of current conductance to an electrically driven, yet in a cardan casing freely movable, gyroscope have been examined in

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great detail. PAVLOV (Section IV - No. 22) hereto renders the results of experiments from which it may be gathered that the following types have been examined in greater detail: centralized peak contacts, level (sliding) contact brushes ("ebene Schleifbuersten"), contact brushes of the Brown Type, roller contacts with a cylindrical and with a rounded path. The most favorable values are shown by the point contacts, as they require an appreciably lower contact pressure for spark-free functioning. Among the various sliding (or brush) contacts or roller contacts, a roller with a rounded path proves to be most favorable because of the friction values. By means of long-term experiments, it has further been ascertained that the same roller contact showed even the slightest resistance changes after ten hours of uninterrupted functioning. In this experiment, the roller, silver-plated, moved in a brace contact path.

Books (Section IV - No. 47, 54 and 55) contain papers, in part very detailed, on such Soviet constructions and productions of further individual parts as are used in the construction of gyroscopic equipment from time to time, for instance: relays, relay or starting motors of low performance, amplifiers, couplings, selsyns and Amplidynes.

III. PERSONAL EXPERIENCES.

A. Gyroscopic Problems in Which the Soviets Have Shown Interest.

1. Improvement of Precision of the Gyroscopic Equipment of the A-4 Rocket.

The first phase of activity of the German rocket specialists in Plant 88, the "reconstruction" of Rocket A-4, with all its individual parts, was practically finished at the end of the year 1946, as the most important part of this work already had been done in BLEICHERODE. At that time, there was some wavering whether or not to go ahead with farther-reaching constructional changes. It is true that, in discussions, the question had often come up, whether it would not be possible to increase the target-accuracy of the rocket by a more minute adjustment of the gyroscopic equipment. A report which resulted from these discussions, and which I compiled in the year 1947, dealing with the computation of the influence of finishing tolerances and adjustment tolerances on the "on target accuracy" of the rocket, must be reviewed. It is the essential result of this referenced report that we come to the realization that the state of the art regarding finishing tolerances was about as advanced as possible, so that, unless there should be far-reaching constructional changes in gyroscopic equipment, no appreciable improvement on accuracy was to be expected from this approach. The very painstaking experiments which were made by the firm ZEISS in 1946, in adjusting horizons of Type D3a, and verticals of Type EA3a, which were mounted out of individual parts which the firm still had available, had nevertheless brought forth a certain improvement over the original degree of accuracy, so that the question arose, whether it would not be possible to improve the accuracy of the previously established tolerances. This, however, was not done, because obviously one did not wish to generalize on the results of limited experiments before due time. How proud the Soviets were of these results, however, was shown by an episode which occurred in the spring of 1948 in Plant 88 in PODLIPKI. On the occasion of a visit made by leading military men and "ministers" (every second or third visitor was a "minister"), Section Chief CHERTOK lead a group of fat-bellied visitors, bedecked with many decorations, through the rooms where the gyroscopes were set out, with the exception of one room into which we Germans had been shoved for that

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day. Thanks to the volume of voice with which the explanations were made, we were nevertheless able to hear every word and thus learned that the Soviets had succeeded in considerably increasing the accuracy of the gyroscopic equipment and had thereby attained a much greater target accuracy than the Germans had been able to achieve at PEENEMUENDE. As proof he presented the curves relating to the experiments made in the ZEISS Plant in JENA in 1946.

A report compiled early in 1948 on the effect of cardanic flaws on the target accuracy belongs to the same sphere of problems.

During the same period of time, the Russian colleagues of the gyroscope section worked, above all, on the many-sided though subordinate questions of the testing and acceptance specifications. A very detailed set of directions for the execution of the tests also was compiled.

The episode reported above is only one example to prove that in judging concrete figures given by the Soviets, one must always be skeptical. In most cases, for what seem to them practical reasons, they either exaggerate or minimize. Into this category of reports, the following must be included: In 1946, in a German newspaper, it was to be read that the Soviet constructors had succeeded in building a new gyro-compass which, though weighing only one-tenth as much as the standard compasses, yet had twice their accuracy. During my stay in the Soviet Union, I spoke of this to various gyroscope experts, but not one of them had ever heard of it.

2. Simplification of the Steering System of the A-4 Rocket.

The interest of the Soviets in the guide-beam-steered rocket was great, as they hoped by this means to exceed the existing limits of target accuracy, which are dependent on the gyroscopic equipment. If accuracy were to be made dependent on the guide-beam, then the functions of the gyroscope could be limited to the command control for the steering gear, and a simpler type of gyroscopic equipment would suffice. Ideas in this direction aroused great interest with the Soviets. Hence one can understand the interest shown in all work connected with the so-called "Markgraf Gyroscope", sometimes also called "Misch-Kreisel". After some preparatory theoretical reports (by Dr. HOCH and me), the problem was taken up practically also, the more so as the Russians had succeeded in fishing two old, partly rusted Markgrafkreisel from a pile of salvage. These gyroscopes were laboriously reconditioned and then tested in the laboratory. The results were not very encouraging. As I remember, there was a wandering error of about 5°/min. A certain improvement could be achieved by the introduction of a negative, electrical tie down, as it had been discovered that the return power exerted by the lead-in-wires on the rotatable system, was responsible for part of the flaw. After some experimenting to make a constructional change in the lead-in of the gyroscope-drive-current, the suggestion arose to compensate the interference of the return current by a corresponding opposing amount generated electrically in the selsyn which is already a regular part of the equipment. For this purpose, a voltage value, picked off from the potentiometer was put on a second spool of the selsyn and so polarized, that a negative "pull" occurred. Its magnitude could be so adjusted by means of resistances that the interfering positive "pull" could be compensated. Nevertheless, the accuracy attained by this equipment remained unsatisfactory.

The Soviets, however, had pinned themselves down to such an extent -- perhaps through overly intensive advertising of this wonder gyroscope

in high places - that work on the Markgraf gyroscope was continued intensively. This time a number of Russian technicians also were put on this work. Thus a young, quite intelligent engineer named KHOKHLOV, in 1947, wrote a theoretical treatise on the Markgraf gyroscope for his examination. From what insight I had in this paper, I was able to ascertain that it was mainly a comprehensive "going over", of the various theoretical papers by German specialists on this topic. KHOKHLOV passed his examination successfully and then vanished from Plant 88. Nor was I able to find any trace of him in later years. Obviously, however, he is not identical with the author of No. 29 (Section IV).

Other Russian co-workers, whose names I do not remember, have worked on the practical questions of the manufacturing preparation for individual parts of the equipment, for instance, the rotor and the stator. The question of balancing also gained in significance in this connection - and from the fact that in 1948 an order to develop a balancing mechanism for small gyroscopes was given to Branch No. 1, on OSTASHKOV. It is possible to conclude that the preparations for the manufacturing of the gyroscopes already had reached a certain stage. After I had written a purely theoretical report on the balancing problem - practical work I did not wish to attempt because of the prevalent conditions in the Branch - a concrete order to construct a balancing mechanism for the rotor of the Markgraf gyroscope was given to the Instrument Section of the Branch. A mechanism of this type was built with inductive selsyns, amplifier and electron ray oscillograph indicator ("Elektroenstrahloszillographenanzeiger") and, after being tested, was sent to MOSCOW. Later (1950 ?), one of the Russian colleagues from the gyroscope group in Plant 88 came to OSTASHKOV again to receive instruction on the handling of the equipment. Obviously, the Russians were unable to attain any satisfactory results without help from the Germans. At any rate, one can gather from the above that the rotor was copied. In 1951 and 1952, we were able to take a look at some of the equipment which the Soviets had copied. I did not work with them, but I did hear that, all in all, the gyroscopes were working satisfactorily. On the copied equipment it could plainly be seen that the men who built it had been fearful of making any constructional change. Thus, the casing frame which, in the original, had been made by the injection molding process and was therefore correspondingly thin-walled with rib-stiffening, had been minutely but very laboriously copied by means of milling. There was exactly one constructional change. The selsyn moment was somewhat enlarged in such a manner that the spool which is located in the magnet casing was given a larger diameter than it had originally, but this was not done until the German specialists had first made the required computations and experiments. In this manner, it was not possible to mount two spools on the spool frame without having to enlarge the gap clearance of the magnet.

The research on the use of the Markgraf gyroscope for the steering of the G-1 rocket (later called R-10) had progressed sufficiently so that the uniting of the three Markgraf gyroscopes into a tri-axial steering mechanism constructionally formed a gyroscope block. An elastic suspension for this gyroscope block was also built and was to be attached directly to the bottom of the lower container. To the aggregation of problems in point of the simplifying of steering mechanisms must be added some work done by PODLIPKI as early as 1947, in which, in place of a Markgraf gyroscope, an ordinary turn indicator was used, whose indicator value was to be integrated by an integration motor and combined with the initial value. A practical test of such a steering mechanism made on a vibration test stand built in Plant 88 showed that with the equipment used a time constant of too great a value resulted in the indicator, which resulted from the inertia of the integration motor. The steering mechanism was built out of German LGW individual parts which happened to be on hand.

An electro-motor steered by an LGW vibration regulator served as a servo-unit. This research was not continued after 1947 and obviously aroused little interest with the Soviets, as they had meanwhile settled definitely on the Markgraf gyroscope.

3. Gyroscopes as Measuring Instruments.

For the execution of Messina measurements, the Soviets were looking for suitable measuring selsyns for the course angles of the rocket when it occurred to them to use the usual gyroscopic equipment, verticals, and horizontals. Thus it became necessary for us, in a report issued in 1947, to clarify the problems which arose with the use of this equipment as measuring selsyns. And, most important, we estimated the degree of accuracy which could be expected. Similar examinations were also carried on by the measuring group of the steering mechanism section in Factory 88. There Dr. STOLPE had written a report on the use of the Siemens directional gyro, Type KLu4 as a measuring selsyn, and had based his work mainly on an article printed by the firm on this apparatus. In 1949 and 1950, several orders to manufacture equipment for the measuring of rotational speeds were submitted to the measuring section of Branch No. 1 in OSTASHKOV. In accord with these orders, German LGW turn indicators were remodeled as, during our first years in this locality, many of them were still available from the captured equipment. Later, however, these mechanisms became very rare, as many had been taken apart as time went by to remove the potentiometers for use in other measuring equipment. In order to make the required rotational speed measuring ranges attainable, the turn indicators were in part equipped with other springs to pin down the frame. These LGW turn indicators, which are in outer structure completely analogous to the Markgraf gyroscope, and which use the same rotor, were also copied later by the Russians. Oddly, this apparatus was copied with complete disregard of another LGW turn indicator, which had been developed further, although a sample of it was at hand.

4. Other Gyroscopic Equipment.

In the summer of 1948, I was given an order to design a gyroscope horizon which would be capable of a high degree of accuracy - I believe 0.2° - independent of any kind of accelerations. On my pointing out that this assignment could not be fulfilled in so general a form, I finally, after much writing back and forth, (significantly, these preliminary questions were not discussed verbally, but were settled in writing only between PODLIPKI and OSTASHKOV), I was sent an acceleration time graph on which to base my research. Then I discovered that this graph had simply been taken from an earlier German report by SÄNGER-BREDT, in which, in a somewhat Utopian manner, rocket paths round about the earth had been marked. (NOTE: The well-known manned rocket bomber proposal by Dr. E. SÄNGER, in which STALIN is said to have shown considerable interest in 1946).

In point of the research done upon this order, it was necessary, first of all, to try to make clear to the people who gave the order, that the principle of acceleration-free adjustment (the so-called 84-minute principle), the use of which obviously had seemed so promising, was no longer valid for aircraft with considerable vertical accelerations. The adjustment requirement then becomes a function of the vertical accelerations. The research then was limited to the drafting of various possible designs, among which were included the suggestions of Dr. GLITSCHER (formerly Siemens Equipment and Machines). GLITSCHER had shown that an acceleration free adjustment also could

be attained, if one were to introduce an additional spin ("Zusatzdrall") to the left ("Backbord"), whose amplitude would depend on the flying speed. For the suggested equipment, a general error theory was outlined and for the concrete example of the SÄNGER-BREDT path the course of the indicator flaw was numerically computed as a time function. Thereby it was made manifest that the required accuracy for this type of extreme case can never be guaranteed.

When the reports made on this assignment were completed, they were sent to the main plant in MOSCOW; they were never referred to again. Not even once did a discussion of these problems take place and the persons who gave the assignments limited themselves - when it was unavoidable - to sending brief directives by letter to OSTASHKOV. The director of the steering mechanism section, CHERTOK, in Plant 88, functioned as the representative of the persons with whom the assignments originated.

In consequence of research done by Dr. QUESSEL on the SCHMETTERLING rocket, I was assigned, in 1949, to outline an error theory on the SCHMETTERLING gyroscope. In this connection, a relatively short report evolved in which general questions (cardan errors, tumbling errors, support errors) were examined. In this case, the assignment was given by an engineer named LEYENIN from Plant 88 at PODLIPKI, who once attended a discussion at OSTASHKOV.

When, in the fall of 1952, new assignments were given to the few remaining members of the OSTASHKOV group, I was assigned to design and build a directional gyro whose weight was not to exceed 5 kg and which was to have an accuracy of 2°/hour. This assignment, again from CHERTOK's Section, was in charge of an engineer named YURA[illegible], who, during the course of this research, often came to OSTASHKOV and occupied himself with the problem intensively. In the course of the discussions which took place during this project, the requirements were made more workable to this extent, that a weight of up to 7 kg was permitted (the equipment, when it was built, was even a little heavier) and that the accuracy requirement was formulated with greater precision. In the course of an hour, the lead angle was not to exceed the value of 2°, but the lead speed could amount up to 3°/hour. The required maximum working altitude was 14 km (45,920 ft), a value which occurred again in the equipment ordered at the same time (angle of attack and angle of sideslip measuring equipment, statoscope).

The basic conceptions on the design of which a model also was built consisted of: (1) the use of a gyroscopic rotor of symmetrical cross-section; (2) introduction of a low friction oscillatory bearing for the cardan axis; (3) the use of centralized sets of contacts ("Zentralkontaktsaetze) for current transmissions from the casing to the cardan frame and also from the cardan frame to the gyroscope casing; (4) the use of a relay system which, despite the use of centralized contacts, guaranteed complete freedom of rotation of the equipment around the directional axis. In other respects, the construction showed the characteristics usual to directional gyros. Two German gyroscopes of Type KA 7 were used as rotors - as rotors of Soviet make were not at hand, i.e., could not be made available. In order to achieve symmetry, the German rotors were placed opposite each other with the ends of their axes touching and were then joined by a coupling. In experiments, this coupling worked very satisfactorily even when the drive of one gyroscope was shut off.

By means of a pneumatic support of the gyroscope system, the axis of the double gyroscope was always made to precess back into the vertical which is perpendicular to the horizontal of the cardan ring. In order to have

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an adequate blow moment available for support, the casing of the gyroscope was milled out so that the blown air could travel in a manner favorable in point of air flow technique. On the cardan ring, opposite the air opening, shutters were mounted which, in normal position, left the openings exactly half open or half closed.

A Ferrari motor with a "Topfanker" (pot-shaped armature?) of thin sheet aluminum served as selsyn moment for the compensation of the earth rotation. A potentiometer which was to be calibrated directly for geographic latitude regulated the feeding of the motor. In addition, four field coils for the operation of the oscillatory bearings ("Schwinglager") were attached to the cardan frame. In the first design, the oscillatory bearings consisted of two each ball bearings placed one behind the other. Both bearings were joined by a case which had a lever with two pole shoes at its end. These pole shoes moved directly before the U-iron cores of the field coils, through which a "meandering" type of current of about 10 Hz (Hertz) was sent. Hereby it proved necessary to adjust the spools very carefully, in order to attain the greatest possible symmetry of the oscillations of the levers. In cases of unsymmetrical oscillations, the compensation of the frictional force is incomplete.

In order to pick off the course deviations, a system of two potentiometers was used, which had to be taken out of A-4 gyroscopic equipment. In addition to the electrical pickoff, the course deviation was also shown visually, as the rotations of the cardan frame with the compass rose attached could be read from the displacements opposite the adjustable "Sollwertrose" (rated value compass rose). The rated value adjustment could be accomplished manually or by a motor.

Other individual parts of the equipment are: a relay motor with mechanisms for shutting off in the end positions, a "Mäandererzeuger", and a slip ring set ("Schleifringsatz) for the relay system.

The model equipment was nearly completed by November 1953. There was no possibility to test it in its entirety as the special ball bearings for the oscillatory bearings, among several other things, had not been delivered. Only individual groupings of the equipment were tested -- the rotor system with the coupling, the pneumatic support mechanism, the oscillatory bearings, (with temporary ball bearings), and the selsyn moment.

Toward the end of the research on this directional gyro, a report was made, a few days before the Germans were transported out of OSTASHKOV, which included directions for the building of the equipment and also for its testing.

In comparison with the rather detailed research which had been done on horizons and verticals, relatively little work has been done on the integration gyroscope, which is also used in the A-4 rocket. It is possible that, at that time already, other methods of the shutting off technique had been decided upon. In Plant 88, an engineer named SHASHKIN had worked on the I-gyroscope for a while; however, insofar as anything is known about it, he never went beyond testing and describing it. Observations of the ("Schaltfrequenzen" (switch frequencies) of the erection motor resulted, in 1948, in my doing some theoretic research on this topic, just before I was sent to OSTASHKOV. On my advice, some experiments were done on the vibration table at that time, but nothing is known of their results.

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Later integration gyroscopes were also used in the so-called "Bahnmodelle". This equipment was a remodeled form of the Siemens directional gyro, Type Lku4. It contained the original rotor (Type KA5), as well as various individual parts of the cardanic bearings and the equipment was completed by the mounting of a Ferrari-type selsyn.

The stabilized platform ("Stabipla"), which was developed by the KREISEL GmbH, BERLIN, for PEENEMUENDE, was given no attention whatever in PODLIPKI. Obviously, it was not within the province of Plant 88. One of these platforms which had been laboriously put into operation in BLEICHERODE was, indeed, brought to PODLIPKI, but it rusted there in a storeroom. It is to be assumed that no other plant was interested in the "Stabipla". Had it been so, the equipment probably would have been transported there.

5. General Gyroscopic Problems.

In general, only discussions on simple gyroscopic problems were carried on with the Russian engineers who were working in the gyroscopic group at Plant 88. These co-workers were chiefly so-called "young" engineers, who had completed their studies in part and now were due for a few years of practical work. Almost without exception, they first had to be broken into gyroscopic problems. Further, it must be said that neither these "young" engineers nor the few "old" engineers belonged by any means to the elite of Russian gyroscope specialists. They knew the technical literature too little to be able to carry on productive conversations with us. Mainly, their interest always veered back to the more practical questions of construction and testing.

There was seldom any opportunity to talk with good Russian gyroscopic specialists. Once a scientist - whose name I did not understand - came to Plant 88 from a Moscow institute. It turned out that he had read earlier publications of mine, and that he knew these treatises very well. We discussed the problem of support for gyroscope horizons. Obviously, work had been done in this field in the Soviet Union. During the days of the experimental shooting in KAPUSTIN, there were repeated opportunities to speak with Herr KUZNETSOV, the leading gyroscope specialist, and also with some of his co-workers. The conversations with Herr KUZNETSOV naturally almost always centered in the problem of intensifying the accuracy of horizons and verticals, in order to raise the target accuracy of the rocket. Occasionally, however, Herr KUZNETSOV also reported on difficulties experienced in the Soviet Union in the manufacture of gyroscopes. At such times, he made no effort to conceal that, in point of gyroscope building, the Russians had not yet gathered the experience which, for instance, existed in Germany toward the end of the war. They had tried to achieve the needed experience by copying certain equipment with painstaking exactness (for instance, the ANSCHUETZ gyroscopic compass).

Interesting, also, were the discussions in KAPUSTIN held with one of the co-workers of KUZNETSOV, whose name I do not remember. He was an older engineer, who obviously had worked intensively on the problems of gyroscope manufacture for a long time. Among other things, he had worked on the question of low friction bearings for gyroscopes, and he asked for my opinion of a German publication on magnetic suspensions. Obviously, at that time, (end of 1947), the Russians had not yet gathered experience of their own with this type of bearing. I recall, also, that the question of the best type of rotor and the question of waves, elastic or rigid, were discussed at that time.

In later years, I never saw Herr KUZNETSOV or his co-worker again.

In the spring of 1948, I had shown gyroscope instructional equipment to Herr OTRESHKU , then in charge of the gyroscope group in Plant 88, for the purpose of explaining some gyroscopic effects. He requested that I demonstrate this equipment before a larger group of the Russian co-workers at Plant 88, also, which I did in two lectures which were interpreted by a woman interpreter. After that the interest in this piece of instructional equipment mounted to such an extent, that Herr OTRESHKU was able to persuade the Russian chiefs of the plant to copy the model. The measurements of the equipment actually were taken by a Russian woman engineer, but it never came to my knowledge, whether the model ever was copied. At the time, I had donated to the plant library a copy of the instruction book belonging to the equipment, an easily comprehensible introduction into the field of gyroscope theory. This book, however, was borrowed by the engineer KARDASH , who was most intensively interested in this piece of instruction equipment, and who disregarded all requests to return it. It was said that the book was to be translated into Russian, but of this, also, I never heard anything further.

B. Soviet Gyroscope Equipment.

The only gyroscopic equipment of unequivocal Soviet origin which I had in my hands during my stay in the Soviet Union was, in 1947, an aerial horizon and an aero directional gyro, and again in 1951 a copy of the German LGW turn indicator.

The first pieces of equipment were put at our disposal because, during the early part of our stay, we had expressed the wish to be able to compare Soviet constructed equipment with the well-known foreign constructions. In the case of the horizon, we noted no appreciable change as compared to the Sperry construction. Externally, however, the impression was of greater bulk and clumsiness. The same is true of the directional gyro. I recall distinctly, however, that in one point it also deviated appreciably from the other well-known constructions. The gyroscopic system around the inner cardan axis was not supported perpendicular to the plane of the outer cardan frame, but perpendicular to the "Scheinlotrichtung" (imaginary vertical reference line). For this purpose a pneumatic support mechanism, which was analogous to the support mechanism of the Sperry horizon, had been mounted at the side of the rotor casing which, in the main, also corresponded to that of the Sperry horizon. The air-jet of the gyroscope thus was blown out through two slits (the Sperry gyro has 4 slits), and was steered by two small pendula corresponding always to the position of the "Scheinlot" (imaginary vertical plane).

No experiments were made with these two pieces of equipment, as at that time PODLIPKI was not equipped to put pneumatic gyroscopes into operation.

C. Individual Parts of Gyroscopic Equipment.

Regarding important individual parts, we only learned, in 1953, of the existence of special double ball bearings for the manufacture of low friction oscillating cardan bearings. In designing the previously-discussed directional gyro, which was to have an exceptional degree of accuracy, it was at first planned to mount the oscillatory bearings by setting two normal ball bearings, one behind the other. In order to obtain the precision bearings with especially narrow tolerances, which are necessary for these bearings, a permit was required from a ball bearing consultation office located in a ball bearing plant in MOSCOW. When an engineer named KISELOV , who was in charge of the construction section of the OSTASHKOV Branch, took these construction drawings to

this place in MOSCOW to order these bearings, he was told, after the drawings had been examined, that he should have the construction changed, as a new double ball bearing especially for use in gyroscopic equipment had just been developed. It had not yet been included in the norms but would be available soon. We were given the data on the bearings (as far as I recall the inner diameter was 6 mm) as the basis of the construction changes. The bearings consisted of three concentric cylinder rings with beveled tracks, between which two crowns of balls moved in ball housings. The middle ring of the bearing had on one side 4 borings 90° apart, with M-1 thread to fasten the actual oscillatory mechanism.

We saw no constructed ball bearings of this type.

In 1953, when preparations were being made to test the planned directional gyro, we were issued another part for gyroscopic equipment, a copy of the German direct current - three-phase current "transformer" ("Gleichstrom-Drehstrom Umformer") of Type GDU-180, put out by the OEMIG CO. Outwardly, the "Umformer" was not to be distinguished from its German model; however, some change had been made in the wiring of the plug connection. Strangely, it was planned to entrust us with the equipment but not with the circuit diagram. Not until we stated our regret at being unable to make any experiments under these conditions were we given a short, penciled outline of the wiring. After being in operation for some time, the "Umformer" (continuous current transformer) proved itself to be usable; only the adjuster control which belonged to it did not prove very constant. This was due to the poor quality of the selenium rectifier which had been used, a fact which previously had given rise to serious interference in the installing of Russian selenium rectifiers into magnet amplifiers.

In the preliminary work for the construction of the directional gyro in the fall of 1952, it was repeatedly stressed that a suitable rotor with a symmetrical cross-section would have to be obtained. This question was debated back and forth between the Russian installations at PODLIPKI and OSTASHKOV several times with the result that, after a long time, the answer finally came that in the Soviet Union there were no gyroscope rotors of this type.

A further bottleneck which made itself acutely felt was the lack of suitable potentiometers, such as were usual for the pickoff of measuring values in gyroscopic equipment. In OSTASHKOV, these were also used for other sensitive measuring instruments (accelerometers, extensometers, pressure gauges, etc.). Although the manufacture of measuring equipment was often demanded by Russian offices with increasing urgency, it was nevertheless impossible to obtain the so urgently needed potentiometers, so that there is reason to assume that in the Soviet Union they either did not exist at all, or only in very inadequate numbers. Thus, in the Branch, it became necessary again and again to fall back on salvaging instruments out of captured German equipment which, at the beginning, was at hand in unlimited quantities.

D. <u>An Estimate of the General Situation in the Field of Theory and Use of the Gyroscope</u>.

Any summarizing of the publications made or of the results gained by personal experience can only be attempted with the most careful restraint. Setting apart the subjective character of any estimate in this field, one must be very careful to avoid generalizations and hasty judgment. It must be kept in mind that, in the Soviet Union, the situation in all fields differs so greatly and is so manifold that observers located in different places and at different times can arrive at totally different conclusions. I, myself have become

very careful due to the tremendous discrepancy which existed between the partly excellent scientific publications on the one hand, and, on the average, the shockingly low degree of knowledge and ability of the specialists with whom we came in contact, on the other hand. Certainly I would recommend similar caution to anyone who undertakes to express judgment on Soviet conditions.

This preliminary comment seemed necessary to me, as a critical estimate of the situation and of Soviet capabilities in the field of gyroscope theory and technique is now to be attempted.

The Soviet Union has a large number of excellent specialists in the field of general gyroscope theory. The Russian tradition in this field which has existed for about 70 years has scarcely ever been broken and has been furthered in the last decade with considerable intensity. One has the impression that, in research of this kind, all practical questions are intentionally avoided, so that the purely analytical character of the research should not be disturbed. Sometimes, however, only the joy in formal mathematics seems to have been the mainspring, because an astonishingly sparse content will be found hiding behind a glittering mathematical front. The worship of theory, which is an important factor in the universal communist viewpoint anyhow, offers a welcome, fertile soil for such manifestations of degeneracy.

Although the Soviet Union also can look back upon a certain amount of tradition in point of applied gyroscope theory, yet one has the impression that this branch is still very young. The founders of applied gyroscope theory, KRYLOV, NIKOLAY and BULGAKOV, who meanwhile have died, have obviously no successor who can match their ability. Perhaps ROYTENBERG, a pupil of BULGAKOV, who is now a professor at the Moscow University, could be called the leading figure of the day in this field. In addition, however, there does exist a series of good scientists who merely have not been very active as yet in this particular field. Among these I would like to count METELITSIN and TKACHEV. KOSLOV, who works in the JUKOVSKI Air Academy must be named here too, and perhaps KOSHLYAKOV, who works in the Institute for Precision Mechanisms and Optical Instruments at LENINGRAD. SHIPANOV, on the other hand, can be by-passed as being of lesser significance. His voluminous book has marked him too much as a man of large [illegible] but of little performance. The data on hand are insufficient to make possible an estimate of the other gyroscope specialists whose names have become known, FRIEDLAENDER and ISAKOVICH (both in MOSCOW), TIKHMENEV (pupil of BULGAKOV), LEVENTAL, DANILIN and KHOKHLOV. A certain special position is held by OKUNEV who, however, seems to have been working exclusively on the application of gyroscope manifestations on flying projectiles.

Only a few papers exist on which an estimation of the development and construction of gyroscopes could be based. Although the books of PAVLOV and SOLOVEV show that a certain activity was going on in this field, yet we must not forget that, above all, both books owe their existence to the fact that many papers by other scientists, predominantly foreign ones, were collected first. In this point, a leading role seems to have been played by KUZNETSOV who was in charge (or the chief engineer) of a MOSCOW institute, which has been active in this field for decades and which previously had been working on marine gyroscopes (gyro-compasses and stabilizing gyroscopes for ships). That he was among the leading personalities is corroborated by the fact that he was a member of a receiving commission which, in the years 1938-1940 came to Germany to get the gyroscopic equipment which had been constructed there for the Soviet Union.

Attachment A

It seems to me that two things hinder the development of the construction of gyroscopic equipment in the Soviet Union: (1) lack of practical experience, and (2) the inability of the Russian engineers to grasp the meaning of "development". To compensate for the lack of practical experience is a slow process, but I have the impression that many efforts are being made in this direction. Considering the many young specialists put to work in this field, and in the Soviet Union there are a great many of them, it will not be surprising if, after a few more years, a sufficient number of trained personnel shall be available. It will probably be more difficult to change the attitude of the Russian engineers toward the tasks to which they are assigned. During my stay in the Soviet Union, I learned to know only the "cook book" type of engineer, i.e., engineers who solve their problems with the help of a number of reference books, which contain a formula for any case which may arise. Further, the conviction is predominant that any equipment which has been diagrammed on paper simply must function immediately without the slightest difficulty, and therefore may be constructed in quantity. The conception of "developing" anything seems to be unknown to the Russians, in fact, the Russian language does not even have an equivalent for this word. The word "Razrabotka", which is often used to designate "development", is by no means the same thing.

It is due to the "cook book attitude" of the Russian engineer that every machine builder exerts himself to adhere to patterns as closely as possible, and to avoid any greater basic changes of construction. This is understandable since, for many years nothing was done other than to copy existing equipment as faithfully as possible. For this activity, the Russian language has a word of its own "Rekonstruktsiya", which can be only imperfectly translated because this conception just is not used, at least not in occidental countries. There is no shortage of mechanics in the Soviet Union, the more so as this particular professional branch enjoys special esteem in popular opinion. By far the greater number of mechanics, however, are trained to do more or less coarse locksmith's work. In the course of my activity in the Soviet Union, I did, to my astonishment, encounter a few excellent precision mechanics. These were young people who, after proper guidance, accomplished different tasks with the greatest patience and devotion; thus, for instance, the winding of the spools for the selsyn of the Markgraf gyroscope, or the adjusting of the rotor or of the cardan bearings. Of course, for this purpose these young people had to be protected from something which, in Russian workshops, is a matter of course -- the constant, harassing driving by the foreman that a prescribed time schedule be followed at all costs. If this was done, and the interest of the mechanics aroused, then they rendered perfect work.

Comment has already been made on the Russian gyroscope specialists who have become known through their publications. I am now adding briefly a few characteristics of the gyroscope specialists with whom I became personally acquainted during my stay in the Soviet Union. In general, I may say that not one of these men was a first class specialist. In most cases, their level lay considerably below what, in Germany, was considered to be average. The most intelligent of these men were [illegible]HO[illegible]HLO[illegible], a young engineer who wrote his examination treatise in Plant 88 in PODLIPKI on the Markgraf gyroscope, and YURA[illegible], who was in charge of a group in NII 88 in 1952/53, and, in this capacity watched over the assignments which were sent to OSTASHKOV.

Concerning OTRESHKU, who was in charge of the gyroscope group in NII 88, I can only say, that he was a fair, courteous and not unpleasant official, but that he was markedly empty of any ideas in the field of gyroscope technique. He occupied himself predominantly with directions for and directives

regarding the testing of gyroscopes. Shortly before the Germans were transferred to OSTASHKOV, he was relieved by a woman engineer, but remained with the group as a co-worker. The names of the other Russian co-workers in the gyroscope group I no longer remember, nor would any special capabilities or characteristics of theirs be worth mentioning. Usually they were young engineers who were only temporarily assigned to the gyroscope group.

During 1947/48, the group for integration gyroscopes was in charge of a person named CHASHKIN, a man of little ability but great industry and ambition. For as long as I knew him, he occupied himself only with the least important matters of the A-4 integration gyroscope.

Another person who was interested in gyroscopes was a man named KARDASH, a co-worker in the servo-unit group in PODLIPKI, 1947/48. Although he was obviously superior in intelligence to the two above named group leaders, he never had a place of any significance in the Plant.

An engineer named LEYENIN was a member of another section of Plant 88, which was headed by a Herr RASHKOV. This section worked at the "reconstruction" of the anti-aircraft rocket SCHMETTERLING. The engineer LEYENIN had a quiet, reserved manner, but he was not especially efficient. His ability, however, was probably adequate for the post he had to fill, for he only needed to describe equipment which was already in existence -- among others the SCHMETTERLING gyroscope -- and to put it in motion.

In 1952/53, I became acquainted with an efficient, older co-worker from Plant 88. His name was MIKHAILOV. Although he did not work directly with gyroscopic equipment, it was obvious that he was well informed in this field. He was in charge of several assignments on various types of vibration tables which, at this time, were being executed in OSTASHKOV. Obviously, these vibration tables were also planned for the testing of gyroscopic equipment.

KUZNETSOV already has been mentioned as one of those gyroscope specialists who did not belong to Plant 88. In BLEICHERODE, in 1946, I further became acquainted with an engineer named FROLOV, who worked very intensively on details of the construction of the A-4 gyroscope -- for instance, the selsyn and potentiometer pickoffs. FROLOV suddenly appeared in Plant 88, in the year 1947, and asked me, in the presence of some other Russians, whether I would not like to go with him to LENINGRAD. There I would again be able to work on torpedo gyroscopes. I never heard of him again.

IV. LITERATURE INDEX.

In this index, the papers are listed according to the date of their publication.

Papers which were available to the author and on which special reviews were written are designated by underlining their numbers at the left.

1. A. N. KRYLOV and A. A. KRUTKOV. "General Gyroscope Theory and Some of Its Technical Applications". Moscow 1932. 2nd Edition, 1936.

2. B. V. BULGAKOV and S. S. TIKHMENEV. "The Theory of the Sperry Gyroscopic Horizon with Pendulum-Steered Air Bearing"; Nachrichten der staatlichen Moskauer Universitaet. (News from the Moscow State University). Vol VII. 1937. pages 181-199.

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5. G. V. HIPANOV. "Gyroscopic Equipment for Blind Flying. Theory, Computation and Construction Methods". State Publishers for Defense Industry. Moscow-Leningrad, 1936.

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Attachment A

AIR INTELLIGENCE INFORMATION REPORT

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Otdeleniye-technich[illegible] nauk, 1948. No. 4

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58. G. A. SLOMYANSKIY "On the Integration of the Motion Equations of a Symmetrical, Astatic Gyroscope". Periodical: Prikladnaya Matematika i Mekhanika. Vol 17, 1953. Pgs. 411-422.

59. L. N. SRETENSKI. "The Motions of the Goryachev — Chaplygin Gyroscope". Periodical: Izvestiya Akademii Nauk, Otdeleniye tekhnicheskikh Nauk. 1953. Pgs. 109-119.

60. V. A. PAVLOV: "Aeronautical Gyroscopic Equipment". State Publishers for the Defense Industry, Moscow, 1954.

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62. N. G. CHETAYEV. "On the Stability of the Rotations of a Rigid Gyroscope About a Fixed Point in the Case of LaGrange". Periodical: Prikladnaya Matematika i Mekhanika. Vol. 18, 1954. Pgs. 123-124.

63. V. V. RUMYANTSEV. "On the Stability of the Rotations of a Heavy, Rigid Gyroscope About a Fixed Point in the Case of S. V. KOVALEVSKAYA" Periodical: Prikladnaya Matematika i Mekhanika. Vol. 18, 1954. Pgs. 457-458.

64. V. V. RUMYANTSEV. "The Motion Equations of a Rigid Gyroscope Which Has Cavities on the Inside, Partly Filled With Liquid". Periodical:

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Prikladnaya Matematika i Mekhanika. Vol 18, 1954. Pgs. 719-728.

65. V. V. RUMYANTSEV. "On the Motion Equations of a Rigid Gyroscope with Liquid-Filled Cavities". Periodical: Prikladnaya Matematika i Mekhanika. Vol. 19. 1955. Pgs. 3-12.

66. P. V. KHARLAMOV. "An Integrable Case of the Motion Equations of a Heavy, Rigid Gyroscope in a Liquid". Periodical: Prikladnaja Matematika i Mekhanika. Vol. 19, 1955. Pgs. 231-233.

67. V. V. RUMYANTSEV. "On the Stability of the Propeller Motion of a Rigid Body in Liquid Under Conditions According to S. A. CHAPLYGIN". Periodical: Prikladnaya Matematika i Mekhanika. Vol 19. 1955. Pgs. 229-230.

P. V. KHARLAMOV. "An Integrable Case of Motion Equations of a Heavy, Rigid Body in a Liquid". Periodical: Prikladnaya Matematika in Mekhanika. Vol. XIX. 1955. Pgs. 231-233.

Tying in with research done by S. A. CHAPLYGIN, a new case is brought forward, in which the motion equations for a rigid body in an infinitely expanded, ideal, incompressible liquid are integrable . This is a case in which the center of gravity of the rigid body does not coincide with the center of gravity of the mass of liquid it displaces. Further, there is here a generalization of the well known case of LaGrange, for which a certain advance motion is now admitted. The author succeeds in finding the solution for nutation angles and precession angles in the form of elliptical integrals. For a further simplified special case for this solution, the author examines the stability of the motions found by determining a LIAPUNOV Function. The solution for the definity of this function then renders the required stability conditions.

V. V. RUMYANTSEV. "On the Stability of the Propeller Motion of a Rigid Body in Liquid Under Conditions According to S. A. CHAPLYGIN". Periodical: Prikladnaya Matematika i Mekhanika. Vol. XIX, 1955. Pgs. 229-230.

CHAPLYGIN has set up the equations for the general motion of a rigid body in an infinitely expanded, ideal, incompressible liquid, and has shown that, in special cases, four integrals of these equations can be given and the problem thereby led back to a quadratic. RUMYANTSEV now states a special solution for the CHAPLYGIN equations, which correspond to the case of a constant propeller motion (screw motion) of a body in liquid. The stability of this propeller type motion may now be determined by examining the interference motion. After the pattern of CHETAYEV, the author creates a LIAPUNOV Function out of three particular integrals, from which the stability requirements may then be determined by means of the known "Forderungen nach Definitheit". In special cases of non-progressive motion, these go over into the known stability requirements for the case examined by S. V. KOVALEVSKIY.

G. V. SHIPANOV. "Gyroscopic Equipment for Blind Flying. Theory, Computation and Construction Methods". State Publishers for the Defense Industry. Moscow-Leningrad. 1938. 423 pages. Edition 6,000.

According to the foreword by the author, this book may be regarded as an immediate continuation of and supplement to the book, "Theory, Computation and Construction Methods of Aviation Equipment" (by the same

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ABSTRACTS OF SOVIET ARTICLES AND BOOKS ON GYROSCOPES

V. V. Rumyantsev: "The Equations of Motion of a Rigid Body Containing Hollow Spaces Partially Filled With Liquid", Prikladnaya Matematika i Mekhanika, Vol 18 (1954), pp 719-728.

Zhukovskiy treated the same subject for the case of hollow spaces completely filled with an homogeneous incompressible liquid. The author expands the earlier investigations by including the case of hollow spaces only partially filled with an homogeneous, incompressible, and frictionless liquid, which means that there is also a free surface of the liquid. In the derivation of the equations of motion, based on the Hamilton principle, the following are assumed:

1) The body is rigid.
2) A constant pressure prevails in the areas of the hollow spaces which are not filled with the liquid.
3) The components of motion of the body and of the liquid normal to the boundary surface of the hollow space are equal.

Liquid and body are considered a single mechanical system. The pressure forces transmitted between the liquid and the body at the boundary surfaces are therefore internal forces and are not included in the equations of motion. In all there are four equations. The first equation expresses the theorem of momentum for the forward motion; the second expresses the theorem of momentum for the rotation; the third equation is a Euler equation of motion for the liquid transformed to the co-involved solid system of coordinates; the fourth equation is the continuity condition for the liquid. Generally speaking, the equation system is extremely complicated. It is considerably simplified, however, in a few special cases, for example, when the hollow spaces within the body are completely filled with liquid, or when the body has a fixed axis of rotation, or when certain conditions of symmetry are satisfied for the body or the hollow spaces within it.

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Under certain conditions some first integrals of the equations of motion can also be given: an energy integral, insofar as forces effecting the system have a force function, and an impulse integral, insofar as the forces around one of the axes produce no moment. For the case of a symmetrical gyroscope with symmetrical hollow spaces within it, for which the forces produce no moment around the figure axis, the fact that the rotation velocity of the system around the figure axis is constant can be computed as an additional integral.

<u>V. V. Rumyantsev</u>: "On the Stability of the Rotations of a Heavy Solid Body Around a Fixed Point in the S. V. Kovalevskaya Case", <u>Prikladnaya Matematika i Mekhanika</u>, Vol 18 (1954), pp 457-458.

In connection with a completely analogous investigation by Chetayev for the case of a Lagrange gyroscope, the author investigates the stability of the rotations for the case of the Kovalevskaya gyroscope in which the center of gravity lies on an equatorial axis. Following the example of Chetayev, he forms a Liapunov function out of the partial integrals of the equations of perturbed motions and arrives at the desired stability condition because of the demand for definity. This necessary and sufficient condition combines the moment of gravity of the gyroscope with the moment of inertia around the axis of the figure. The motions in respect to both the rotation components and the cosine of direction of the axis of the figure are stable if the condition is satisfied.

<u>N. G. Chetayev</u>: "Concerning the Stability of the Rotations of a Solid Body Around a Fixed Point in the Lagrange Case", <u>Prikladnaya Matematika i Mekhanika</u>, Vol 18 (1954), pp 123-124

The conditions of stability for the Lagrange case are derived for the most part from the Euler gyroscope equations. The author attempts to derive this condition of stability according to the so-called direct method of Liapunov. For this purpose he sets up equations of the perturbed motion

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in respect to the three components of rotation, which are fixed in respect to a body, and the three cosines of direction of the axis of the figure, from which four integrals can be given. A Liapunov function can be constructed from these integrals. Out of the demand for the definition of this function the known stability condition can be found, which requires for the momentum component of the gyroscope around the axis of the figure a minimum value depending on the moment of gravity and the equatorial moment of inertia.

V. N. Koshlyakov: "Concerning Certain Special Cases of the Integration of the Dynamic Euler Equations Connected With the Motion of a Gyroscope in a Medium With Resistance", Prikladnaya Matematika i Mekhanika, Vol 18 (1953), pp 137-148.

When a gyroscope moves in a medium with resistance, corresponding forces are exerted on it. If these forces have certain mathematical relationships, the appropriate Euler equations can be integrated. To the already known cases of this type (calculated by Krutkov and Bulgakov) the author adds a new one. He first treats a slightly asymmetrical gyroscope for which the external moments around the main axes of inertia are proportional to the corresponding components of momentum. The calculation in this case is only possible thru an expansion in a power series, in which the assumed small relative asymmetry of the gyroscope is used as a parameter of expansion. The calculation is carried thru in this case as far as the first approximation. The result is that the influence of this asymmetry of the gyroscope is insignificant as long as the asymmetry is actually small.

If the gyroscope is symmetrical, and if the external moments are similarly disposed, a strict solution of the equations can be given with the aid of the Bessel function. Theoretically, the solution can also be given for the case where the external moment is additionally dependent on the time.

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The case, in which the moment around the axis of the figure is assumed to be proportional to the square of the rotation velocity, has a practical significance, since this case occurs when the gyroscope is moving in air. The equations of motion can then be solved in an elementary way only for definite values of the coefficients entering into the equations. Even with a successful solution of the dynamic Euler equations, in all cases investigated thus far there remains the difficulty of computing the Euler angle out of the kinematic Euler equations.

In the last part of the article the author returns to a problem treated by him before in regard to the theory of the artificial horizon and brings up the question of the errors in indication which can arise with a change of the rate of spin of the gyroscope. He is especially interested here in the case where the power which drives the gyro is suddenly cut off and the gyro runs down. If in such a case an exponential drop in the rate of a spin is assumed, a solution can be found with Bessel functions of the zero order. In the case of a hyperbolic drop, on the other hand, cylindrical functions are obtained. In both cases the result of the drop in the rate of spin is a damped motion.

L. I. Tkachev: "Concerning the 84-Minute Period in Systems with Fixed and Free Gyroscopes", Prikladnaya Matematika i Mekhanika, Vol 18 (1949), pp 217-218.

The author shows that the 84-minute period is not exclusively a characteristic of systems in which the gyroscope is pendulous, although until now only such cases have been treated in the literature.

If an artificial horizon is produced in such a way that the gyroscopic couple of a fixed gyroscope is measured and combined with the values of two accelerometers in a computer, it can be shown that this system also has a period of 84 minutes, if the synchronization is unaccelerated.

The same can be shown for a system which has a free gyroscope instead of a fixed gyroscope. The free gyroscope serves actually only as a basis for the two instruments which measure the acceleration components. The

gyroscope in this case has a fixed direction in space independent of the earth's rotation. The horizon indication is a purely mathematical value produced from the integrating device. In this case too, with sporadic perturbations of the indication of the horizon, a period of 84-minutes is obtained.

This article, which is only two pages long, has a purely theoretical significance. No suggestions are given for any practical applications.

G. A. Slomyanskiy: "On the Integration of the Equations of Motion of a Symmetrical Astatic Gyroscope", Prikladnaya Matematika i Mekhanika, Vol 18 (1953), pp 411-422.

The author integrates the equations of motion of a symmetrical, astatic, Cardan mounted gyroscope with the use of a reference system which is rigid in space and conforms to the Cardan suspension. He neglects the mass of the Cardan suspension. Although a few first integrals for the general -- not linearized -- problem can be given, the complete solution is attempted only for three special cases.

A strict solution with the help of elementary functions is possible in the case of the force-free gyroscope. The results obtained cannot be expanded to larger ranges of tilting of the inner Cardan ring, since the influence of the mass of the suspension neglected in the calculation would then become considerable. The "clinch-position" of the Cardan mounted gyroscope, which occurs when the inner ring is rotated 90°, does not appear in these calculations as a singular point.

In the case of a constant external moment around the inner Cardan axis the strict solutions can be given only in integral form. A better approximate solution is obtained when the angle of nutation changes only slightly. In this way generally valid formulas for the general regular precession are obtained, which can still be further simplified for the case of the fast spinning gyroscope.

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Finally the solution of the equations of motion is given for the case where a moment around the inner axis depends on the angle of rotation around this axis. In this case also only a first integration is possible, so that the general solution can only be given in integral form.

P. A. Kuz'min: "An Addition to the Steklov Case of the Motion of a Heavy Gyroscope Around a Fixed Point", Prikladnaya Matematika i Mekhanika, Vol 16 (1952), pp 243-245.

The case treated by Steklov in 1899, whereby the motion of an asymmetrical gyroscope, in which the gravity point lies on a main axis of inertia, is considered. By means of a special extension for the gravity moment entering into the Euler equations of motion, a special solution is found for which the three components of the gyroscope rotation can be expressed by the Jacobi elliptical functions.

V. N. Koshlyakov: "Concerning the Error of the Gyroscopic Horizon in Connection With A Variable Self-Motivated Spin of the Gyroscope Roter", Ingenieur-Rundschau, Vol 6 (1950), pp 185-196.

In the first part of the article the linearized equations for the small deflections of the gyroscope are derived, both for a fixed instrument and for the case of an arbitrary horizontal motion of the supporting frame.

In the second part the differential equations for the special case are investigated, in which a rapid but small change of the spin, and therefore also of the gyroscopic effect, takes place. The calculation is done by two Volterra integral equations of the second order, which are solved by iteration. Expansions in a power series are carried out according to the assumed small change in momentum, and the higher series elements are neglected. The numerical evaluation of the calculations shows that the indicating accuracy of the instrument is practically uninfluenced by

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small changes of the rate of spin. Even with a 5% change in the rate of spin, the errors are still smaller than 10 minutes of arc.

In the third part the influence of periodically successive changes in the rate of spin is investigated. The investigations here likewise show that under normal conditions there is no appreciable effect on the accuracy of the instrument. In certain practically unimportant areas resonance phenomena can be produced, such as are known to occur in systems with periodic coefficients.

V. V. Rumyantsev: "On the Equations of Motion of a Solid Body With Hallow Spaces Containing Liquid", Prikladnaya Matematika i Mekhanika, Vol 19 (1955), pp 3-12.

In connection with articles by Poincaire and Chetayev the author sets up the equations of motion for a gyroscope containing arbitrarily formed internal cavities which are completely or partially filled with a homogeneous, incompressible, and frictionless liquid.

The equations are given in three different forms:

1) a form used by Poincare, but expanded to include arbitrarily formed hollow spaces in a system of coordinates which is fixed in respect to a body;
2) an expanded form of the Lagrange equations of motion in a reference system rigid in space;
3) a canonical form used by Chetayev, which can be considered an expansion of the Hamilton equations.

Both conservative and non-conservative forces are considered in the derivation. Solutions or formulations of solutions for the equations of motion are not given.

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N. N. Bautin: "The Behavior of Dynamic Systems in the Vicinity of the Stability Boundaries, monograph in the series "Modern Problems of Mechanics", State Publishing House for Technical and Theoretical Literature, Moscow-Leningrad (1949)

In this monograph the author shows how in nonlinear systems the question of danger or lack of danger of the stability boundary, produced by a linear treatment of the same system, can be solved. He ~~basis~~ bases his procedure on earlier investigations of Liapounov and shows that the question of the danger or lack of danger can be decided by the sign of a "Liapounov function".

Among his several examples are ~~tow~~ two gyroscope problems: a gyro-stabilized single track railroad and a ship stabilized for pitch and roll by gyroscopes. In both cases the gyroscope is used as a stabilizer which produces stabilizing moments directly. The difference between the two systems lies in the fact that the containment of gravity in the gyroscope system for the single-track railroad is negative (center of gravity above the point of suspension), whereas in the case of the ship's gyroscope it is positive (center of gravity below the point of suspension).

In both cases the results of the investigations are plotted without dimensions. With the single-track railroad there are two critical values for the size of the viscous damping around the axis of the frame for every value of the gyroscopic moment. Below the smaller value and above the larger value the system is unstable. The investigation shows, with the help of the Liapounov function, that exceeding the upper boundary is not dangerous, but merely leads to vibrations of limited amplitude; exceeding the lower boundary is dangerous, however, since there is an increase of the amplitudes, and the system changes to another state of equilibrium.

In the case of the ship's gyroscope the lower critical boundary value for the frame-damping drops out, so that the portion of the stability boundary corresponding to the upper value is not dangerous. If this portion of the boundary is exceeded, oscillations will build up, but the extent to which they can build up depends on the degree to which the boundary is exceeded. If the boundary is exceeded only slightly, only very slight

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vibrations will be produced. A return to within the boundary will bring an end to the vibrations. The system is reversible, but exceeding the boundary at dangerous portions leads to nonreversible conditions.

A. F. Khokhlov: "On the Use of a Gyroscope-Magnet as a Course Indicator", Avtomatika i Telemekhanika, Vol 8 (1947), No 4, pp 285-296.

Here the interesting attempt is made to combine the two traditional methods of course indication, gyroscopic and magnetic. In contrast to the well-known combinations of this type, wherein the magnetic needle is used only as a control for the correction moment, there is in this case a fixed connection between gyroscope and magnet. The magnetic north-south direction coincides with the rotational axis of the rotor.

For such a device the author sets up a linearized theory for which at the outset a quite special condition must be satisfied. This condition combines the gyroscopic moment and the maximum magnetic moment with the values for the rotational velocity of the earth, the geographical latitude, and the magnetic inclination. The fulfillment of this condition provides a simple calculation of the system of differential equations, but it would require, for practical application, such an enormous gyroscopic moment, that the oscillating system, because of the magnetic containment, would have a period of 12 hours at the equator, which would increase to 24 hours at 60° latitude. In view of the great difficulties involved with the much shorter Schuler period of 84 minutes, it is obvious that the investigation here has only theoretical value. There are no suggestions for a practical application of this gyroscopic device.

One advantage of the fulfillment of the above condition is the fact that the position of equilibrium of the gyroscope axis is horizontal and forms the mid point between the meridian and the magnetic north-south direction, when the condition $\varphi = \mu$ (i.e., geographic latitude = magnetic inclination) is fulfilled.

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When the stated conditions are satisfied, the directional force of the instrument is twice as great as that of a standard gyrocompass; the course errors are therefore only half as large under otherwise similar conditions.

Since the gyroscope of the instrument is supposed to be astatically mounted, it receives its directional force solely from the moment of the magnet connection to it. The instrument considered by the author therefore carries out undamped oscillations around its position of equilibrium. For the damping of these oscillations the same means are employed which have been tested for damping the oscillations of a gyrocompass during adjustment. The author does not go into further detail on this subject. It is to be expected, however, that the extremely high oscillation periods will produce new difficulties in regard to the damping.

B. V. Bulgakov: "The Compounding of Errors in Gyroscopic Apparatus", Ingenieur-Archiv, Vol 11 (1940), pp 461-469.

In the study of errors in the gyroscopes of moving vehicles or aircraft consideration is usually limited to certain typical forms of motion, such as the uniformly accelerated straight-line motion or a circular motion with constant velocity. Even though the results obtained in such cases are sufficient to judge the applicability of a device, there is always the danger that certain combinations of forms of motions will lead to a compounding of errors. In this regard the author attempts to find for a given gyroscope those motions which will produce a maximum error, and to calculate this error. He is successful in doing this for a gyroscopic compass.

The well-known linearized equations of motion for a gyrocompass (Anschuetz-compass) are solved with the aid of operators, whereby the earth's rotation and curvature are taken into consideration. The azimuth deflection, produced in addition to the course error by the accelerations

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of the ship, is obtained in the form of an integral into which the corresponding time functions of the ship's maneuvers are entered. For the most common case, where the period of a ship's maneuver is small compared to the period of natural oscillation of the compass, the integral can be substituted by a simpler and more easily evaluated expression.

From the discussion of the error formula it is clear that the ship's maneuver which produces the largest theoretical error is an alternate rapid changing of course from north to south and vice versa. The error produced in such a case is the sum of a convergent series. For actual maneuvers, where the change of course would be much slower, much smaller errors are to be expected.

The calculations are considerably simplified when the Schuler 84-minute condition is maintained. The resultant error is then caused solely by the damping of the gyrocompass. As a result of the Schuler condition, the error is equal to zero for an undamped gyroscope.

In a practical example with actual figures, already worked out by Geckeler, the maximum error is computed and found to be in good agreement with the strict value obtained by Geckeler.

<u>A. A. Krasovskiy</u>: "Concerning an Oscillatory Method of Linearizing Certain Nonlinear Systems.", <u>Avtomatika i Telemekhanika</u>, Vol 9, No 1, pp. 20-29

A theory is developed expressly for the vibration mounting of gyroscopic devices, whereby the author bases his work on the general theorems derived by Bogolyubov, which state that the behavior of certain nonlinear systems in which there are forces of comparatively high frequency can be approximated under certain conditions by the behavior of a linear system whose characteristic curves have been obtained from the original system by a process of interpolation.

The method is illustrated by two examples (simple oscillator with Coulomb friction and a hydraulic servo-motor with a Servo-piston). The author also gives the results of experiments in which the change of a friction force was measured by superimposed oscillations as a function of

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the amplitude of these oscillations. Unfortunately, the text does not tell how these experiments were carried out.

B. V. Bulgakov and S. S. Tikhmenev: "Theory of the Sperry Gyroscopic Horizon With Pendulum-Air Blast Correction", News of the Moscow State University, Vol 7 (1937), pp 181-199

The authors present a linearized theory of the Sperry horizon for the following moments:

1) moment of air-blast support,
2) moments of friction around the two Cardan axes,
3) disturbing moments of gravity in the case of such great path deviations that the control pendula are deflected.

The solution of the linearized equations is accordingly carried out in four different zones:

1) very small course changes within which the correction moment is smaller than the friction moment;
2) the range adjacent to 1) up to a complete opening of the control slit by the pendula;
3) the range in which the pendula release the control slits completely, but do not reach maximum deflection;
4) large course deviations after maximum deflection of the pendula.

The solution to range 4) is not carried out, but simply stated qualitatively.

The second part of the article treats disturbing influences such as the changes of indication resulting from the earth's rotation and speed of the aircraft. In the case of the latter, only the longitudinal accelerations are investigated in detail, whereby a table of possible maximum horizon errors is given for the case of constant longitudinal acceleration and a given maximum flight velocity. The case of curved flight is mentioned only briefly.

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The numerical evaluation was carried out for an original Sperry instrument.

L. N. Sretenskiy: "The Motion of the Goryachev-Chaplygin Gyroscope." (dedicated to the memory of S. A. Chaplygin), News of the Academy of Sciences of the USSR, Department of Technical Sciences, No 1 (1953), pp 109-119.

Goryachev investigated the motions of a gyroscope whose main moment of inertia satisfied the condition A = B = 4C and whose center of gravity lies in the equatorial plane of the inertia ellipsoid. Chaplygin produced a generalized integration of the Goryachev case with the use of ultra-elliptical integrals. The Goryachev-Chaplygin results are now treated in detail for a specialized case in which a gyroscope has received a large initial moment around a main axis of inertia which passes thru the center of gravity. The motions are then analogous to the so-called pseudo-regular precession in the case of the Lagrange gyroscope.

The expressions in the Chaplygin integrals are developed in series, wherein the higher members can be neglected because of the assumption of a large initial moment. The most important result of the investigations is the fact that the gyroscopic axis, about which the moment takes place, oscillates with a decreasing and then increasing amplitude (vibration). The oscillation frequency is thus proportional, and the vibration frequency inversely proportional, to the initial natural rotation of the gyroscope. The natural rotation itself changes in time with the vibrations.

G. O. Fridlender: "On the Precession of a Gyroscope Under the Effect of an External Moment", Ingenieur-Rundschau, Vol 12 (1952), pp 229-233.

Since investigations on the effect of external moments on a gyroscope generally are limited to the behavior of the gyroscopic axis, i.e., one of the three main axes of inertia, the author investigates the motion of the

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instantaneous axis of rotation and the likewise instantaneous axis of momentum. He limits himself to the case of the rapid moving gyroscope which is supported at its center of gravity.

Under the effect of any external moment acting upon the gyroscope, the well-known motions of the gyroscopic axis on a point-, loop, or wave-cycloid are produced, according to the chosen initial conditions. The author gives for these cases the corresponding motions of the instantaneous vector of rotation and vector of momentum. The drawings given for these cases do not appear to be very reliable, since, for example, one point cycloid is obviously erroneous.

The author mentions the interpretation of Klein and Sommerfeld for the case of the pseudoregular precession, which, similar to the case of Poinsot, describes the motions of the gyroscope by the rolling of a sphere which is fixed in respect to a body on a sphere which is rigid in space.

From these considerations it may be concluded that the moment due to the friction of the air acting on an erratic free gyroscope causes the gyroscopic axis to rise upward, just as the moment of friction of the point on the base.

Ya. N. Roytenberg: "Self Oscillations of Gyroscope Stabilizers", Prikladnaya Matematika i Mekhanika, Vol 11 (1947), pp 271-280

Here the behavior of a gyroscope stabilizer is investigated, in which a Cardan-suspended gyroscope during precessions around the inner Cardan axes activates a potentiometer which, via an amplifier, turns a stabilizing motor.. The motor provides a moment around the external Cardan axis; this moment imparts to the stabilized system joined with the external Cardan axis a certain insensibility toward external perturbation moments.

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The author investigates the case where the potentiometer has a black-white characteristic of the form S sign β , whereby β is the angle of rotation of the gyroscopic system around the inner Cardan axis. The calculation itself is carried out linearly by area, and the individual solutions then are bunched at the transition point. By entering the condition of periodicity a periodic solution of the system can be found, for which the stability is determined by investigating a system of differential equations.

From an example worked out with actual figures by the author, it is evident that the investigations concerned rather large objects, such as are used in the navy, for from the given data it is evident that the stabilized system has a weight of between $\frac{1}{2}$ ton and 1 ton, and the gyroscope itself might weight about 20 kilograms. The stabilizer motor has a rated current of 6 amperes and produces a stabilized moment of 0.45 kilogram.

I. I. Metalitsyn: "On the Question of Gyroscope Stabilization", Doklady Akademii Nauk SSSR, Vol 86 (1952), No 1, pp 31-34.

In the investigation of stability according to the Hurwitz method, the influence of individual types of forces on the stability cannot be overlooked. The author thus separates his linear system in such a way that the various forces (inertial forces, dissipative forces, gyroscopic forces, conservative forces, and intrinsically nonconservative forces) are entered independently in the stability equation. In this way, he obtains six general rules, which can be of great advantage in the projecting of dynamic systems.

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1) When a conservative system is statically unstable, it can not be stabilized by the addition of intrinsically nonconservative forces (without dissipative and gyroscopic).

2) When a conservative system is statically stable, the adding of intrinsically nonconservative forces can make the system unstable.

3) An intrinsically nonconservative system can be stabilized only if gyroscopic and dissipative forces are added simultaneously to the effective forces.

4) A statically unstable system can be stabilized, if dissipative, gyroscopic, and intrinsically nonconservative forces are added simultaneously to the effective forces.

5) If the condition of stability is satisfied, and if the gyroscopic forces are superior to the other forces, the oscillation frequencies of the system separate, that is, the one becomes relatively large, the other relatively small.

6) If the stability condition is satisfied, and the gyroscopic forees are superior, the oscillation with the larger frequency will be more strongly damped than the oscillation with the small frequency.

D. G. Topel'bert: Electronavigational Instruments. State Publishing House for Water Transport, Moscow-Leningrad (1950), 428 pages, 3000 copies, prices 17.60 rubles.

This book, written by a captain in the navy, serves as a text at the advanced training schools of the navy. The greater part of the book (276 pages) is devoted to the gyroscopic instruments used in navigation, chiefly the gyrocompass. The two other sections deal with the Echolot (fathometer) and log.

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The introduction to the gyroscope theory in the first chapter is quite extensive, in view of the purpose of the book. The theoretical considerations are based chiefly on "technical" gyroscope equations. The equations of approximation used are those usually employed in the consideration of "small oscillations". They are not derived directly here, but obtained indirectly by means of a linearization of the generalized Euler equations. The mass of the Cardan rings is neglected, and it is assumed that the vector of rotation deviates only slightly from the pronounced main axis of inertia. The precession and the effect of brief disturbances are then investigated on the basis of these simplified equations. For later investigations an expansion of the equations of approximation for rotating systems of reference is necessary.

In the following three chapters (2 to 5) a rather detailed theory of the first approximation is presented for a gyrocompass damped by an eccentrically suspended pendulum and for a gyrocompass with damping tanks. Then the behavior of the gyrocompass on a moving ship is treated, and the theory of the course error and the acceleration error is developed. The condition (Schuler) for an acceleration-free period-adjustment (84-minute principle) is also derived. The question of counteracting the ballistic deviation of the first type leads to the necessity of adjusting the undamped instrument to a natural oscillation period of 84 minutes. The question of counteracting the ballistic deviation of the second type leads to the necessity of either using an undamped instrument, or of cutting off the damping during maneuvering (changes of course and speed).

The quadrantal error of the gyrocompass is also investigated, and methods of correcting it are shown. These observations are, however, more qualitative than quantitative.

Essentially, the theory developed in the book is based on that of the well-known text on gyroscopes by Krylov and Krutkov (1932).

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All the values which can be used to judge the operation of a gyrocompass are compiled in a table, and methods are indicated whereby the individual values can be determined by laboratory tests. The degree of accuracy required in these cases is $\pm$ 0.1° for laboratory work and $\pm$ 0.2° to 0.3° for work on an anchored ship.

Chapter 6 presents an elementary theory of the artificial horizon, but only insofar as the horizon is maintanied by means of a gravity moment. This theory suffices for the Fleuriais gyroscopic sextant described in the book.

There is also a brief discussion of a gyroscopic device with which the geographical latitude φ can be measured. The operating principle is based on the fact that the indications of both the gyrocompass and the artificial horizon are functions of the geographical latitude φ. If the exact heading and the exact horizon are known from another source, the geographical latitude can be determined from the difference. It is emphasized, however, that such instruments are not yet sufficiently accurate for use in navigation.

In Chapter 7 the designs of two gyrocompasses are given in great detail. The first one described is a single-gyroscope compass, presumably built in the USSR. Its rotar has a diameter of 25 centimeters and weights about 23 kilograms, and is thus much heavier than the single-gyroscope compasses of other countries. The gyroscope system is suspended in a very interesting manner by means of wires, and is provided with guide bearings and a vertical control system, which compensates any return moments resulting from the twisting of the suspension wires. Damping tanks of the usual type are used. The course error is eliminated by a special "corrector", which used the speed and geographical latitude as initial data.

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The second gyrocompass is the two-gyroscope "spherical compass" of Anschuetz and Company (the firm is not mentioned, however). The three-gyroscope compass is not mentioned.

The following chapters deal with the installation of the gyrocompass on board ship, testing the installed compass, and evaluating the obtained data. The discussions embrace all the instruments connected directly or indirectly with the gyrocompass, such as repeaters, current-supply equipment, course recorders, flight recorders, and autopilots.

Ya. L. Geronimus: Survey of the Works of the Classicists of Russian Mechanics, State Publishing House for Technical and Theoretical Literature, Moscow (1952), 519 pages, 5000 copies, price 22.75 rubles.

This book is a valuable contribution for two reasons. First, it gives a brief but clear survey of many works which would be difficult to compile and review individually; secondly, the work based on the classics in Russian mechanics is followed down to very recent times (about 1950), thus an extensive and valuable bibliography is supplied.

In the chapter on S. V. Kovalevskiy, in addition to a discussion of the "Kovalevskiy case" (a special case of the heavy symmetrical gyroscope), the other classical cases are discussed, in which an integration of the equations of motion for the ordinary gyroscope was possible. There are also brief discussions of the works of Euler-Poinsot, Lagrange, Appelrot, Bobylev-Steklov, Hess, Goryachev-Chaplygin, and of the investigations made by Zhukovskiy with a gyroscope in a liquid. Especially interesting in this case is the analogy between the curvatures of an upright wire with an elliptical cross section subjected to a force and a moment at the free end and the motions of the usual asymmetrical gyroscope.

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In the chapter on Steklov the work on the gyroscope turning in a liquid is discussed, and a corresponding survey of later works on this theme is given. These purely analytical-mechanical investigations have not been continued in recent times; nor are there any known practical applications of this theory.

The chapter on Krylov gives only a brief description of the work which is presented in great detail in the book by Krylov and Krutkov.

Ya. V. Linnik and V. S. Novoselov: "Random Disturbances of the Regular Precession of a Gyroscope", Prikladnaya Matematika i Mekhanika, Vol 18 (1953), pp 361-368.

Over half of this article is devoted to purely mathematical investigations on the probability distribution of the solutions of a system of differential equations. These investigations are finally applied to the case of the regular precession of a symmetrical gyroscope, whose moments of inertia and gravity are subject to certain random changes. A Gauss distribution is assumed for these changes.

Formulas are given with which the density of probability for the deviations of the gyroscope motions from the regular precession can be computed from the corresponding matrices of correlation.

V. V. Golubev: Lectures on the Integration of the Equations of Motion for the Rotation of a Rigid Body Around a Fixed Point, State Publishing House for Technical and Theoretical Literature, Moscow (1953), 287 pages, 8000 copies, price 6.15 rubles.

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This book represents an expansion of lectures delivered at the University of Moscow. It is called by the author a continuation of the book on the analytical theory of differential equations (published in 1950) and concerns the application of the methods of the theory of analytical functions and the analytical theory of differential equations to the classic problem of the rotation of a rigid body around a fixed point. The author states that his special task is the application of modern analytical methods to practical cases. In this connection he quotes Chekhov, who once said, "If a pistol is drawn in the first act of a play, it should be fired by at least the third act." The author draws up some heavy artillery, such as the theory of elliptical, hyperelliptical, and ultraelliptical functions, Abel integrals, and Riemannian spaces, and lets go with a loud noise. The book deals much more with mathematics than with physics; at many places mathematical problems are treated which have nothing at all to do with the gyroscope. In many instances it is evident that the author's preference for mathematical analysis does not necessarily represent the shortest path toward a solution of the problem at hand.

To a certain degree the book is a tribute to S. V. Kovalevskiy, since references to the work of Kovalevskiy both in the introductory historical survey and in the text itself are inordinately frequent.

In the final chapter the author even cites and discusses portions of correspondence with Kovalevskiy. The basic idea, with which Kovalevskiy obtained the classical results, is developed in detail by the author and presented in the light of modern analytical methods. This idea is that in the solutions of the equations of motion the time can be considered a complex value, and thus the theory of functions can be drawn upon for the solution of the problem.

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In comparison with the detailed treatment of the Kovalevskiy case, the well-known other cases, in which the basic equations of the gyroscope can be integrated, are treated only briefly. These cases are:

1) Euler - Poinsot
2) Lagrange - Poisson
3) Hess - Appelrot
4) Goryachev - Chaplygin
5) Bobylev - Steklov.

In all these cases special assumptions are made concerning the form of the inertia ellipsoid or the position of the center of gravity, or both, to the extent that a fourth integral can be added to the well-known three integrals of the equations of motion, and the solution traced back to a quadrature. Under such conditions, elliptical integrals appear again and again, and the reversal of them leads to the solutions. More than 50 pages of the book are devoted to these reversals of elliptical intggrals.

On the whole, the book can be considered a presentation of the classical integrable cases for the motion of a gyroscope in the light of modern methods of mathematics.

V. A. Pavlov: Principles of Design of Gyroscopic Instruments, State Publishing House for the Defense Industry, Moscow (1946), 6000 copies, 223 pages, 16 rubles

This textbook of the Institute of the Aircraft Industry is intended for designers who are concerned with the development of gyroscopic devices. The author, therefore, presents a compilation and summary of the many methods which have been developed for the design of small and light gyroscopic devices, in order to save many designers the trouble of solving partial problems which have already been solved in principle.

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After a short historical introduction, the first five chapters deal with a broad but not always clear introduction to the general gyroscope theory. For instance, on pages 33 to 35 there is a superfluous and much too involved derivation of the general theorem of the conservation of areas. The theory is developed to such an extent that the equations of approximation, which apply for small deviations in the gyroscopic axis and which are sufficient generally for the calculation of gyroscopic phenomena and gyroscopic instruments, are derived. No special theory for gyroscopic instruments is given, but in the later chapters there is an explanation of the methods by which certain individual parts of gyroscopic instruments can be calculated.

Chapter 6 presents a general survey of the various uses of the gyroscope, without going into great detail. Only foreign designs are discussed. The gyrocompass, the first gyroscopic device to be put to practical use, is mentioned only briefly, since the book is written not for the navy but for the air force. The most varied designs of directional gyros are discussed in great detail. Along with the discussions of such types as Anschuetz, Obry, Sperry and Brown, there are also descriptions and partial data given on instruments made by Ach, Hartmann and Braun, and the gyroscopic control instrument for guns made by Krupp. The basic behavior of these instruments, especially the deflection caused by the earth's rotation, is discussed. The single-track-railroad gyroscope of Shilovskiy is the only gyroscopic stabilizer mentioned. Of special interest are the descriptions of two test gyroscopes, both referred to as "accelerographs", but which do not actually measure accelerations. The one is a free gyroscope with three degrees of freedom, which is used to record the angle of rotation; the other is simply a turn indicator (gyroscope with two degrees of freedom and spring mount), with which the turning speed can be measured.

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The following chapter deals with the subject of methods of powering the gyroscope, and the advantages and disadvantages of the various methods (pneumatic drive with Venturi tube or pump, electric drive with direct or alternating current) are compared. The author comes to the conclusion that the use of three-phase alternating current is best, because of greater accuracy, constant speed, more rapid attainmant of full speed, and the fact that no heating is necessary.

Special importance is then ascribed to the "choice of the principal scheme" of the gyroscopic devices. Using a directional gyro with a rated accuracy as an example, the author shows how data on the physical properties of the rotor and ball bearings can be applied to obtain a minimum value for the momentum, at which the required accuracy ban be maintained. An attempt is made to summarize the various designs of the past decades as a basis for predicting the trends and needs for the future. Only foreign designs are again mentioned here in respect to actual practical examples.

The remaining chapters are devoted to the individual parts of gyroscopic instruments. In the discussion of the rotors the influence of air- and bearing friction is considered, and a detailed analysis of the various cross-section forms and dimensions is worked out. Although the designs mentioned here are again exclusively foreign, there are figures given in various tables and charts for unidentified gyroscopes, which may possibly be of Russian design. Two of these gyroscopes are small and relatively light (714 and 788 grams), whereas the other three are 124 and 136 millimeters in diameter and weight from 2.9 to 3.3 kilograms. The problem of material for the rotor and the calculation of the strength and critical speed of the rotor shaft are investigated.

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The ninth chapter, the largest in the book, deals with the problem of bearings for the rotor and the Cardan rings. Detailed calculations of ball bearings and pivot bearings are given, and data is compiled on the friction, tolerances (axial and radial) and strength of all types of ball bearings. A table for Russian ball bearings is also given. The problem of bearing size, which is difficult because of the lack of knowledge of the expected stresses of the individual axes, is facilitated by the compilation of emperical data (table on page 137).

In the discussion of the Cardan suspension attention is paid chiefly to the problem of reducing the friction by means of pivot bearings. A great number of designs are discussed, most of which are foreign. The effects of bearing friction and tolerances, which are extremely important in a Cardan suspension, are treated in the text and in diagrams and tables.

Chapter 10 contains a discussion of the most varied types of correction devices which are necessary either for compensating the effect of the Earth's rotation on the gyroscope or for maintaining a given direction with the aid of a magnetic needle or a pendulum. The difference between the indicators which determine the deviations from the desired position and the members which provide the correction moments is emphasized. The various types of correction-moment producers and their advantages and disadvantages are discussed, and their characteristic curves are presented in diagrams.

The last two chapters treat the power supply equipment and the controlling gear. This is a very well organized compilation of otherwise widely scattered information on the friction of sliding-, brush-, and roller contacts and the contact resistances of the various types of power supply. Presumably the data represents the results of Russian investigations, most of which were carried out on foreign equipment.

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In the discussions of controlling gear one unidentified design stands out as especially primitive and is possibly a Soviet model. All the other items of controlling gear mentioned are the well-known instruments of Sperry, Siemens, Anschuetz, and Obry. The calculation of the stresses which controlling gear must assume is also important.

The book presents a systemmatic compilation of data which is of great value to the designer. Even though the dessriptions of Soviet instruments or parts of instruments are infrequent, they do point to the basic trends in Soviet gyroscope development.

Handbook for the Designer of Precision Instruments (Spravochnik Konstruktora Tochnykh Priborov), I. Ya. Levin, Editor, State Publishing House for the Defense Industry, Moscow (1953), 616 pages, price 23 rubles.

This extensive handbook contains a great deal of important details for the designing of gyroscopic devices. Especially important are the nearly 100 pages of data on the various types of Soviet ball bearings, which include not only the usual norms but complete information on the friction and tolerances of special bearings of the type used in gyroscopic instruments.

A. I. Nekrasov: A Course in Theoretical Mechanics, State Publishing House for Technical and Theoretical Literature, Moscow-Leningrad (1945-1946), 2 volumes, 355 pages and 456 pages, price 9.50 rubles and 14.50 - rubles.

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Only a very small part of this textbook for the higher technical schools and universities contains information on the gyroscope theory. Kinematics is treated only briefly in the first volume. The second volume presents a somewhat more detailed presentation of the concepts of moment of inertia, inertia ellipsoid, energy-, and momentum ellipsoid, but the actual gyroscope dynamics is limited to a brief treatment of the Euler case of the force-free asymmetrical gyroscope and the Lagrange case of the heavy symmetrical gyroscope. In the first instance, the procedure is exclusively that of Poinsot without the use of elliptical functions. In the second case, the solution is indicated, but not carried out.

There is a brief account of the various uses of the gyroscope.

V. N. Okunev: The Free Motion of the Gyroscope, State Publishing House for Technical and Theoretical Literature, Moscow-Leningrad (1951), 379 pages, price 14 rubles.

The book deals with the motions of a gyroscope with three degrees of freedom rotating around a fixed point in a coordinate system. The investigations are carried out in an analytical form and in keeping with the classical gyroscope theory. The Euler angles are used for the most part to describe the motions of the gyroscope, but the designation "swing angles" is also used, which offers certain advantages in the investigation of small oscillations of the gyroscope.

The book treats only a part of the classical gyroscope theory, however, but the material presented is fully treated. In his endeavor to provide a full treatment, the author frequently includes material which is obviously not relevant. The expansiveness of the book is due in part to the fact that the author presents each formula in its most explicit form and frequently repeats a formula given earlier in the text instead

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of merely referring to it. There are places in the text where groups of formulas are given, which are quite imposing, but not necessarily distinct. The presentation itself, however, is generally quite clear and understandable.

In the first part of the book both the well-known connections between the Euler angles and those of the "swing angles" and their connections with the Euler angles are to ge found. The fact that the so-called "regular precession" is defined kinematically only and treated fully in the introductory chapter is unusual. Epicycloidal, pericycloidal, hypocycloidal, and anticycloidal motions are investigated.

In the discussion of the asymmetrical gyroscope the author avoids a presentation of the Poinsot motions and gives only the usual integration of the Euler equations with the aid of the Jacobi elliptical functions. The solutions are then simplified for certain special forms of the inertia ellipsoid and discussed.

The greater part of the book deals with heavy symmetrical gyroscopes. The free gyroscope (center of gravity above the support point) and the pendulous gyroscope (center of gravity below the support point) are treated separately. The influence of friction on the motions of the gyroscope is treated in particular detail, whereby three different cases are distinguished:

1) The friction moment is perpendicular to the gyroscope axis and proportional to rotation speeds of the gyroscope axis;
2) The friction moment is in the direction of the gyroscope axis and is proportional to the intrinsic rotation velocity of the gyroscope axis;
3) The vector of the friction moment has both an equatorial and axial component.

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Unfortunately, these extensive investigations cannot be applied directly to the conditions for a Cardan suspended gyroscope, since the "swing angles" used are not identical with the angles at the Cardan Suspension. As indicated in the preface, the author is more concerned with the application of his theory to the motions of free-flying rotating missiles. All these investigations in which the friction is taken into account are simplified to the extent that only small deviations of the gyroscope axis from known motions are assumed.

The last part of the book contains a series of results and diagrams of trajectory curves which are not to be found in other books.

<u>L. G. Loytsyanskiy and A. I. Lur'ye</u>: <u>A Course in Theoretical Mechanics</u>, State Publishing House for Technical and Theoritical Literature, Moscow-Leningrad (1948), 2 volumes, 399 pages and 580 pages, price 13 rubles and 18 rubles.

This extraordinarily extensive textbook on theoretical mechanics, which is widely used in the Soviet Union, contains a seventy-page treatment of the gyroscope theory which includes some applications of the gyroscope in practical use.

In the first volume of the work kinematics is treated in the usual manner, except that there is an unusual amount of vectorial presentation, which provides in many places a degree of clarity to otherwise cumbersome formulas. Here too, the most general case of the motion of a rigid body (combination of rotation and translation) is investigated.

After introductory discussions of centrifugal- and inertia moments and energy and momentum on rotating rigid bodies the second volume presents a theory of approximation for gyroscope phenomena, with the aid of which certain technical applications (Obry's gear, nautical gyrocompasses by Schlick and Sperry, single-track railroad of Scherl, Shilovskiy and

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Brennan) are investigated. This theory is limited to the symmetrical gyroscope. For the asymmetrical gyroscope only the well-known Euler equations are derived, but not integrated.

The case of the heavy symmetrical gyroscope is considered for "small oscillations", and this theory is applied to the motions of rotating missiles.

Much interesting and important material is to be found here on the gyrocompass, gyroscope single-track railroad, and the investigation of the edge-runner mill.

S. A. Ginsburg, I. Ya. Lekhtman, and V. S. Malov: The Principles of Automatics and Telemechanics, State Publishing House for Power Engineering Literature, Moscow-Leningrad (1953), 432 pages, price 9.75 rubles.

This is a textbook for engineers and technicians in the field of automatics. It contains descriptions and elementary calculations of the predominantly electrical components which are found in servo mechanisms. Since many of these components are used in gyroscope instruments, these descirptions have a certain importance. Some of the subjects treated are:

Potentiometers

inductive oscillators

capacitive oscillators

piezoelectric oscillators

relays

electromagnetic couplings

miniature motors

torque-producing elements

machine amplifiers (amplidyne)

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magnetic amplifiers

tube amplifiers

photoelectric amplifiers

selsyns

magnesyns

bolometers

self balancing bridges

Data is not given for all these components, and it is not evident from the description whether the products are of Soviet or foreign manufacture.

A. M. Bogdanov-Cherrin: Mechanics in Aeronautical Engineering, State Publishing House for the Defense Industry, Moscow (1952), 443 pages, price 11.65 rubles.

This is a textbook for aeronautical engineers, technicians and mechanics. It presents an elementary introduction to mechanics by means of examples from the field of aeronautical engineering. Since the book is intended for students with only a Soviet intermediate school education, no differential calculus is included.

The astonishing thing about this book is the fact that the gyroscope, which has such a wide application in aeronautical engineering, is not mentioned at all, with the exception of a completely elementary example of kinematics. This fact is all the more astonishing since the gyroscope laws and some simple applications of the gyroscope are treated in the Soviet intermediate schools.

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G. K. Suslov: Theoretical Mechanics, State Publishing House for Technical and Theoretical Literature, Moscow-Leningrad (1946), 655 pages, price 25 rubles.

This textbook on theoretical mechanics contains an astonishingly detailed (117 pages) account of the general gyroscope theory. Much of the material presented here is to be found only in the handbooks. The description is limited to purely theoretical considerations, and no attention is paid to practical applications.

In the introductory chapters the equations of motion of a rigid body are derived in the most generally valid form (6 degrees of freedom, various types of coordinate systems and various necessary conditions). These equations are then simplified for the well-known classical special cases and integrated.

These cases are:

1) the Euler gyroscope (i.e., the foree-free Poinsot and McCullagh motion);
2) the Lagrange gyroscope (a heavy symmetrical gyroscope, whose center of gravity lies on one of the main axes of inertia);
3) the spherical gyroscope (i.e., a gyroscope whose three main moments of inertia are all equal);
4) the Kovalevskiy-gyroscope (i.e., a symmetrical gyroscope with quite special inertia ellipsoid and with the center of gravity in the plane of symmetry);
5) the Hess gyroscope (an asymmetrical gyroscope with quite special location of the center of gravity and special initial momentum);
6) the Bobylev-Steklov gyroscope (in which the moment of inertia around the main axis, on which the center of gravity lies, is twice as great as one of the two other moments of inertia).

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In the treatment of all of these cases well-known principles or effects are often given little known designations — a phenomenon which is extraordinarily frequent in Soviet literature.

Non-holonomic systems are also treated. For example, a general formulation of the d'Alembert principle for this case is given, and a very general case of the sphere rolling on a space is treated, whereby a coordinate system rotating with the curvatures of this space is used.

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BOOK REVIEWS

German manuscript [redacted]

Ye. L. Nikolai: Giroskop i nekotoryye yego tekhnicheskiye primeneniya [The Gyroscope and Some of Its Technical Applications], with comprehensive introduction, State Publishing House for Technical-Theoretical Literature, Moscow-Leningrad, 1947, 152 pages, first edition, 15,000 copies, price 2.25 rubles.

This small book is one of a popular scientific-technical series which are published in the Soviet Union in large numbers and in many editions. It contains an elementary theory of simple gyroscopic phenomena as well as of a series of gyroscopic devices. According to the author's preface, the book directs itself primarily to such technicians and mechanics who do not possess special mathematical or physical training, but who deal with gyroscopic devices. For readers with some higher training, considerations are interspersed in notes at various points of the text, which however are also fully elementary in scope. The attempt to explain the simplest gyroscopic phenomena (precession and gyroscope moment of a directed gyroscope) without use of the impuse law and without explaining the vector concept leads partly to quite tedious and by no means clear explanations.

In the discussion of the gyroscope, in addition to the generally known devices (Obry's torpedo, Howell's torpedo, gyroscopic course indicator, turn-and-bank indicator, monorail, gyrocompass, and artificial horizon), a device is mentioned which is designed for use in airplanes, and with whose aid pitch and yaw may be determined. It

simply involves a built-in horizon displaced by 90 degrees and possesses a somewhat different indicating installation. Particulars as to whether this device is being built in the Soviet Union are lacking. In the discussion of the monorail one learns that during the twenties the construction of an experimental line between Leningrad and Gatschin was planned. This project, however, was never carried out since the preliminary experiments were unsatisfactory.

The gyrocompass, to which the author devotes an entire chapter, is explained very thoroughly and broadly in the Sperry design form. The mode of operation of the two damping methods (eccentrically guided pendulum and antirolling tank with mercury) is explained in detail. It is rather surprising that during the otherwise quite detailed discussion of the various errors (course error and acceleration error) the rolling error is not mentioned at all, and nothing is said about the triple gyrocompass.

Ye. L. Nikolai: Teoriya giroskopov [The Theory of Gyroscopes]. State Publishing House for Technical-Theoretical Literature, Moscow-Leningrad 1948, 171 pages, First edition, 10,000 copies, Price 6 rubles.

The book provides a short, more or less elementary theory of gyroscopic phenomena with consideration given to various applications of the gyroscope. It presents a revised and extended version of gyroscopic theory found in the author's textbook on theoretical mechanics. The presentation is very broad and detailed, yet quite comprehensible as is frequently encountered in Russian textbooks.

The following are noteworthy in the treatment of the gyroscopic

theory.

1. The use of generalized Euler equations (Section 8), i.e. of gyroscopic equations which are written in an arbitrary reference system not fixed with respect to a body. Their use provides advantages in the treatment of many applications of the gyroscope.

2. The use of a complex calculating method (Sections 28 and 35) for the theory of the symmetric gyroscope, which, although not new, is not commonly used.

3. A theory of the gyroscope mounted on gimbals (Chapter VI) in which the mass of the gimbal rings is considered. The equations are derived, however, no solutions are investigated.

A rather detailed description and theory of the various gyrocompass designs is presented in the treatment concerning the applications of the gyroscope, in addition to a series of smaller examples (grinding pressure of edge-runner mills, suspension reactions of unbalanced rotors, gyroscopic forces of rotating machine components on vehicles). The problem of damping is examined in greater detail and an elementary derivation of the course and acceleration error is also presented. The Schuler 84-minute principle is briefly mentioned in this connection, however without indication of closer details. The last chapter treats the question of the critical rates of revolution of elastic waves taking into account gyroscopic effects.

V. M. Shlyandin: <u>Elementy avtomatiki i telemekhaniki</u> [Elements of Automation and Servomechanics], State Publishing House of the Defense Industry, Moscow, 1952, 435 pages, Price 11.85 rubles.

This textbook, written for the training of aircraft-instrument engineers, contains a series of subjects which are also

significant to gyroscope technology. Chapter II contains a detailed survey of the various types of pick-ups including the methods used for calculation (for example, resistance transmitter, inductive, capacitive, and photoelectric pick-ups). Special problems, as for example the construction of transmitters with specified characteristics (sine- or cosine-characteristic) are also treated.

A gyro-induction compass is described in Section X,2. According to the author's information the latest (1952) designs of the induction-compass are included. These consist of a system of three inductive transmitters, each displaced by 60 degrees of the other and each respond to the earth's magnetic field. The only function of the gyroscope is to maintain the three transmitter elements in a horizontal plane. It is loosely stated that the gyroscope is used as a yaw and roll gyroscope without indicating principles or constructive details. By use of the gyroscope, pivoting of the transmitter elements around the horizontal axes is avoided and thus the northerly turning error is almost eliminated. The gyro-induction compass possesses a guaranteed accuracy of ± 2 degrees.

As described in Section X,3 this compass is also used as measurement transmitter of an automatic pilot. By means of this device the path of an airplane may be determined by integration of the pertinent values of course, speed, and wind-force and direction. The pertinent location is directly indicated by means of two hands on the map.

Ye. V. Ol'man, Ya. I. Solov'yev, V. P. Tokarev: Avtopiloty [Automatic Pilots], State Publishing House for the Defense Industry, Chief-Editor for Aeronautics Literature, Moscow, 1946, 472 pages, First Edition, 6,000 copies, Price 30 rubles.

This book contains a description of automatic pilots of all essential systems, foreign as well as Soviet. In addition to a presentation of the historical development of automatic pilots, the fundamentals of a theory of automatic control of airplanes is treated.

According to the author's preface the book is intended for engineers, designers, and developers of automatic pilots and is to serve simultaneously as a textbook for students in these fields.

The book treats an extraordinarily extensive subject field, with instrument technology, undoubtedly, constituting the main theme. In contrast, the occasionally interspersed theoretical considerations, as for example in Chapter II, are hardly significant. The book is essentially of a descriptive nature and enters into details in places. The intensity of the descriptions of the individual designs frequently permits inferences as to how much attention has been paid to the instruments(at least within the author's field) and what significance is attributed to them.

By far the greatest part of the book is devoted to the description of the various designs. After presenting a rather consistent historical survey in Chapter III of the predecessors of today's automatic pilots, the next two chapters are devoted to the description of foreign designs. Finally, Chapter VI contains quite an extensive description of Soviet automatic pilots which were developed during the years 1932 to 1942. In connection with this it is mentioned that "one of the first automatic pilots made in the Soviet Union" is the type ABP-10. This automatic pilot which appeared in 1934 differs from its predecessors ABP-1 and ABP-3 only in details, which, although necessary for safe operation especially at low temperatures, are of no significance to the principle of the instrument. Three-position gyroscopes are still used for this purpose,

which are pneumatically driven and supported and which are differentiated exclusively by the nature of their support.

The developed automatic pilot of the type STL-4 which "was constructed by the designers Selizki, Timofeyev, and Lusis," essentially corresponds to the well-known Sperry-pilot of 1934. The Sperry gyrocompass in conjunction with the Askania telecompass is used as course compass. The Sperry horizon is used for stabilizing the longitudinal and transverse position. Since this design has evidently not proven itself, the Sperry automatic pilot was copied without any change as type ABP-12 and after a specific test period was changed in some details so that the type ABP-12-D was created. These changes concerned measures to extend the temperature range up to -50°C as well as increasing the peak performance of these pneumatic devices. The device evidently must have been used extensively in this form, for the description treats very comprehensively all details of installation, ground, and flight testing.

Chapter VII is devoted to a further development of the automatic pilot ABP-12-D the type AP-42, which stems from the designers Semenov and Ol'man (author of the book). Nothing was changed in the method of control, but a series of construction changes was instituted. Thus in the case of the gyroscopes the arrest of the hitherto copied Sperry gyrocompass was changed. The horizon was evidently accepted without change. At the time the book was drafted this automatic pilot evidently represented the most modern Soviet device of this kind. For this reason very comprehensive descriptions including installation drawings, test instructions, and operating directions, even instructions for eliminating errors, are presented.

Chapter VIII treats the uniaxial directional controls in use

at that time. Conspicuous here is the very intensive concern with the automatic pilots of Askania and Siemens. This explicitness coupled with a critique of the devices permits the conclusion that these types were extensively tested in Soviet Russia, and that they possibly were used as original designs for their own developments. The Soviet automatic pilot control of type AK-1 described in this chapter (a design by engineer Sorokin) is nothing more than the directional control portion from the triaxial control ABP-12, thus from the Sperry control. In this connection it is reported that at the beginning of the war all Soviet passenger airplanes of the type PS-84 were equipped with automatic pilot controls.

In the last chapter of the book, descriptions of the modern American automatic pilots "Sperry A-5" and "Minneapolis - Honeywell C-1" are presented. Tests of these devices at the time the book was drafted had evidently not yet been made, since the authors limit themselves to a relatively short description.

Of interest is the fact that at the end of the book in the tabular survey of the various automatic pilots with their most important characteristics, foreign designs are exclusively used despite the fact that in the book itself Soviet devices are described in detail.

Seen from the standpoint of gyroscope technology, Chapter I possesses another specific significance since in this section gyroscopic devices in general and their individual components are discussed. Here Soviet designs are also briefly described.

GERMAN REVIEW OF RUSSIAN WORKS ON GYROSCOPES

[redacted]

B. V. Bulgakov and Ya. N. Roitenberg, "Concerning the Theory of Power-Assisted Artificial Horizons," Izvestiya Akademii nauk SSSR [News of the Academy of Sciences USSR], Department of Technical Sciences, Vol 3, 1948, Pages 289-292.

This work, which consists of only four pages, is particularly noteworthy because it shows the manner in which the apparatus which was treated in detail by Roitenberg in an earlier publication [redacted] has subsequently been developed and modified. While the original design by Roitenberg in 1946, which provided a Cardan suspended platform on which there were four gyroscopes, was a type in which the system lost a certain directive force by placing the center of gravity lower than the point of intersection, they now have switched over to making the platform systems astatic with the gyroscopes and for this reason having the (power) assistance actuated by small gyro pendulums which are attached to the gyro housing.

This development indicates a distinct parallel to the development of the artificial horizon itself. While the Anschuetz (Dr. Hermann Anschuetz-Kaempfe) artificial horizon still operated with a lower center of gravity location, the later Sperry horizon was astatically located and actuated the (power) assistance by small pendulums.

It is worthwhile to note that this parallelism was not discovered by the authors until quite late. Apparently, they at first thought only of dealing with a replacement, which seemed practicable for the apparatus, of the moment of gravitational force by pendulous controlled

moments without changing any of the principal methods of operation of the mechanism. Only now in this publication is there a reference to the closely related possibility of transposing the assignment of the gyro pendulum to the assisting motor, exactly as has long been the case with the Sperry horizon. The findings of this work consist in the indication that one can synchronize such a system (likewise a Schuler type) to a natural frequency period of 84.4 minutes and that then, except for a course error, no acceleration error (ballistic deviations) will appear.

At the conclusion of their studies the authors indicate that it would be most practicable to unite both methods of assistance with one another so as to attain a damping of the timing oscillations. In this case, therefore, each of the two controlling pendulums would have to be connected to each of the two assistance motors and the polarity of the assistance moments selected accordingly.

Ye. L. Nikolai, Giroskop v kardanovom podvese [The Gyroscope in Cardanic Suspension], State Publishing House for Technical-Theoretical Writing, Moscow, 1944.

The monograph, of 83 pages, essentially contains the results of two earlier publications of the same author, [redacted] The influence of various kinds of friction on the movement possibilities of a Cardanic suspended gyroscope is exclusively studied. Of course, the characteristic sizes of the gimbal rings are not neglected as is usually the case; however, since the author simplifies his equation of motion by linearization, he misses the interesting and, for the technical application of Cardanic suspended gyrocompass, the extraordinarily important effect of the azimuthal variations of the gyro axis under the influence of

the nutation oscillations. If for this reason the monograph must be regarded as obsolete, several partial results still claim considerable interest.

In the first section the equations of motion for a Cardanic suspended gyroscope are arranged in a perfectly common form -- but then, for the case of the "quick gyroscope," they are simplified by the elimination of all nonlinear units. The linear equations thus obtained are then integrated one after another for the following cases:

1. Cardanic suspension without friction and damping but for various sloped positions (because of the nonlinear units not being used in this case, the results are completely invalid).

2. Damping moments proportional to the rate of revolution around the gyro axis.

3. Impedance of one of the gimbal rings -- thereby a loss of the stabilizing properties.

4. Constant external moment, no damping; pseudo-regular precession.

5. Constant external moment with damping proportional to the speed.

6. Simplified calculations of the precession by elimination of the inertia units.

7. Action of the gyroscope in the presence of coulomb friction around the gyro axis.

8. The same case (7) simplified by elimination of the inertia units.

Of the problems listed above, the seventh problem takes up by far the greatest part of the monograph. The author solves this nonlinear problem by the piecemeal joining together of the linear partial solutions by frequency. For this purpose he uses a graph plane which contains the speeds around both gyro axes as the axes of the coordinates. Moreover, he distorts the scale so that the track curves become circles in the single quadrants of this plane and can therefore be easily drawn. From time to time the central points of this arc of the circle jump from one quadrant to another while in transition. With this lengthy explanation of the "method of the image point," several special cases are then discussed in which the total nutational action takes place in one quadrant of the image plane and in which the speeds therefore retain their signs. Such is possible if there are strong external moments and the nutation impulses remain small. In spite of the presence of friction, undamped oscillations can appear in special cases. Moreover, special cases are also possible in which the movement, while transiting, comes to rest in one of the two coordinates.

For the case in which the friction moments remain small as compared to the gyroscope moments, approximate formulas are easily derived. In the case of coulomb friction there also exists a sort of pseudo-regular precession. The nutation amplitudes, however, decline (during the precession) to a certain boundary value for which one of the previously studied stationary movements then adjusts itself with change points. Besides deriving practicably useful approximate formulas for this case, the author still shows that from a measured track curve of the gyroscope apex, the coulomb frictions present in the Cardan suspension can also be determined conversely.

Ya. N. Roitenberg, "The Multiple Gyroscope-Horizon," Prikladnaya matematika i mekhanika [Applied Mathematics and Mechanics], Vol 10, 1946, Pages 101-124.

In his very detailed and valuable work Roitenberg seizes upon the idea which A. N. Krylov had discussed in his book on the "General Gyroscope Theory and its Technical Application." Krylov had suggested for the stabilization of ships, a platform on which two gyroscopes, one each for rolling and yawing, were to be fastened. Instead of the one gyroscope for each axis suggested by Krylov, Roitenberg now takes two gyroscopes and investigates the operation of a system composed of four gyroscopes during various motional conditions of the ship on which the mechanism was to be located.

A valuable finding of this work is shown by the fact that the errors of the 4-gyroscope mechanism can, in part, be considerably smaller than those of a single-gyroscope mechanism with similar data.

The 4-gyroscope mechanism is described in the first section. It consists of a Cardan suspended frame on which the four gyroscopes are so fastened that their housing can rotate around an axis passing vertically to the platform. The rotor axes of each two of these gyroscopes are aligned in the normal position parallel to one another. Their movements around the vertical axis of plane, however, are not independent of one another, but rather are coupled together by rods. The gyroscopes with parallel-lying rotor axes can therefore only turn in an equal, but oppositely located angle around their vertical axis of plane. These rotary motions around the vertical axis of plane are still influenced by spring clamps which continually seek to draw the gyroscopes back to a normal position. The system has a (power) assistance apparatus around the two gyro axes of the platform;

the center of gravity lies under the point of intersection of the two Cardan axes.

In the theory of the mechanism, frictions around the gyro and gyroscope housing axes are eliminated. Moreover, the acceleration units are cancelled out in the manner which is usually approved for technical gyroscope problems and therefore are computed with the "technical gyroscope equations." The rotation and curvature of the earth, however, are included since they are important for further theory.

After dealing with the movement units, the action of the mechanism on an immobile base (laboratory) is then computed. As expected, one gets a timing oscillation and an earth rotation error besides. Since the latter is composed of known quantities, it can be determined by calculation and can therefore be compensated for.

In the calculation of the important rolling error for ships, it is assumed that the mechanism moves on an orbital circle in a vertical plane. For this case one gets a recording error which is significantly smaller for the described 4-gyroscope horizon than the error of a similarly constructed mechanism with only one gyroscope. The error of the single-gyroscope pendulum is proportional to the relationship of the wave frequency to the characteristic gyroscope frequency -- therefore a very small quantity; the error of the 4-gyroscope mechanism on the other hand is proportional to the square of this relationship.

The errors of 4-gyroscope and single-gyroscope mechanisms may also be compared with one another for cases of linear and curve accelerations.

Since a characteristic oscillation period of 84.4 minutes for the single gyroscope horizon had proven especially favorable (Schuler's 84 minute principle!), the author also investigates his 4-gyroscope mechanism with the same modulation. In so doing he comes to the not too astonishing conclusion that when the (power) assistance is switched off, the mechanism does not show a course or acceleration error. Moreover, he can show that the oscillator impulse vector of all four gyroscopes is proportional to the absolute speed of the ship. Each pair of gyroscopes indicates for itself a component of this absolute speed.

Especially important for gyroscope mechanisms is the question of the accumulation of error in a series of different maneuvers, which was first studied by B. V. Bulgakov. Roitenberg studies this question for an 84-minute system. With the aid of the method previously applied by Bulgakov, he succeeds in figuring out the maximum error of his mechanism in the form of a series from error integrals. For a practical example of this, he comes to the conclusion that the maximum possible error of his mechanism during the unfavorable series of different ship maneuvers is exactly half as great as the corresponding error of a single gyroscope mechanism.

The weaker the (power) assistance is around the gyro axes, the smaller is the ballistic error in the maneuvers of short duration.

At the conclusion of his studies Roitenberg again discusses the case of a 4-gyroscope mechanism with a characteristic oscillation period which is considerably smaller than 84.4 minutes. This question is of great practical significance since an oscillation period of 84.4 minutes can only be reached with difficulty. In doing this he comes to the conclusion that in the case of a characteristic oscillation

period which is negligible in comparison with 84.4 minutes, the ballistic recording errors of the 4-gyroscope mechanism are smaller by the factor 1/e than those of a single gyroscope mechanism.

D. A. Braslavskiy, S. S. Logunov, and D. S. Pel'por, Raschet i konstruktsiya aviatsionnykh priborov [Design and Construction of Aeronautical Equipment], State Publishing House for the Defense Industry, Moscow, 1954. 583 Pages, price 19.20 rubles.

This extensive book should be used as a text for schools which are concerned with the development of aeronautical equipment designers. It apparently originated in collaboration with the Mosco Ordzhonikidze-Technicum for Aeronautical Equipment Designers.

The work, which is divided in three parts, discusses first of all, in about 170 pages, general questions of aeronautical equipment design; the second part of the book, almost 250 pages, contains descriptions and designs for the most important aeronautical equipment -- without gyroscope equipment -- while the third part consisting of 150 pages is concerned with gyroscope equipment and automatic pilots.

The introduction of three chapters is a model example for primarily historical introductions as have been customary in the Soviet Union for several years. The reader is spared hardly a single name of all of the many original discoverers in Russia and with an enviable carelessness practically all areas which are connected with aeronautics or its equipment are described as discovered and machined by the Russians. Two sentences, which are supposed to characterize the situation in the gyroscope field, may serve as a typical example:

"In the year 1765, L. Euler, a member of the Russian Academy of Sciences, in his famous dissertation on the theory of the movement of a rigid body, gave a schematic representation concerning the question of the movement of a rigid body around a fixed point. The leadership in general and applied gyroscope theory was later taken over by the Russian scientists A. N. Krylov, Ya. A. Krutkov, Ye. L. Nikolai, and B. V. Bulgakov." Finally, in an introduction which is true to the (party) line, the invocation of the Five-Year Plan and the Communist Party could not be lacking. In the first chapter of the book general requirements for aeronautical equipment are discussed. In addition, structural parts, which are to appear again and again in many mechanisms, are discussed. In a very systematic form one finds here, for example, a tabular survey of 52 different measuring transmitters which, from time to time, are arranged according to input and output amplitudes. Exhaustive descriptions and designs of electrical and mechanical structural parts (potentiometers, inductive and capacitative transmitters,spring arrangement, dampers, etc) can be very valuable for designers.

The second and most extensive chapter of the book has detailed theoretical and descriptive designs of equipment for recording pressure, temperature, quantity and charge of fuel, number of revolutions, altitute, speeds and course deviations with magnetic means.

In the third chapter the most important gyroscope mechanisms are described in about 100 pages and the different automatic pilots are described in an additional 50 pages. It would be interesting to note the names of the most important Soviet researchers which are cited at the beginning (of the chapter): "The development of the fatherland's aeronautical gyroscope equipment is the service of the Soviet designers Ye. F. Antinov, Ye. V. Olman, V. Ye. Sorkin, and

others"... "The most important works concerning gyroscope theory are by the well known Russian scientists N. Ye. Zhukovskiy, A. N. Krylov, Ye. L. Nikolai, B. I. Kudrevitch and, concerning applied gyroscope theory, B. V. Bulgakov. The development of the theory of aeronautical gyroscope equipment came about through the works of S. S. Tikhmenev, A. S. Koslov, Ya. I. Solovyev, G. O. Friedländer, Ya. N. Roitenberg, P. V. Bromberg, V. A. Pavlov, and others."

The turn-and-bank indicator is described as the first of the gyroscope mechanisms. Two design forms are shown, of which the first has a direct current gyroscope and is constructed essentially like the Askania turn indicator; the second, however, is identical with the turn-and-bank indicator brought out by the LGW firm around 1942, in which a gyroscope of spherical shape ("the furious walnut") of 30-mm diameter was used as the rotor. The drawing used in this book has been taken over without any change from an LGW prospectus. The damping gyro, with whose help the rate of revolution and the rotary acceleration can be measured at the same time, is described only in brief and is illustrated in two drawings.

On the other hand, the different horizons are again treated in detail. After a description of the most useful designs (Sperry), we (find) used a general error theory of the horizon and reference made to the possibilities of reducing above all the banking error. For this purpose one can either switch off the traverse (power) assistance during a banking turn or can, however, install the gyro axis in the airplane somewhat inclined in the direction of flight.

A "yaw and roll gyroscope with proportional (power) assistance" is described only briefly. Since for this purpose, however, the most important data and also a photograph are given, one can assume with

safety that this relatively complex mechanism has actually been constructed. It is used, for example, in the automatic control as an indicator for banking turns and pitch. The whole mechanism weighs 8.3 kg and has external measurements of 200 x 263 x 215 mm.

The turn-and-bank indicator combined with artificial horizon which originated with the firm of Horn and which combined horizon, turn-and-bank indicator, and banking level in one housing has been reproduced in Russia. In any case, to a certain extent, considerable changes have been undertaken, for exaple, in the type of recording as well as in the adjustment. Moreover, the Russian gyroscopes work with a rate of revolution of 400 hz., while the German mechanism is is equipped with two 500-hz. gyroscopes. The (power) assistance of the horizon occurs through small mercury spirit levels which make contacts for certain inclinations. Migratory curves have been devised and mentioned in this book for an assistance of this type according to the "yes-no" principle and also for assistance characterized by hysteresis.

Next to the previously named conventional horizon types, the Russians have concerned themselves with the question of aerobatic horizons and have even built a mechanism of this type. However, the description is so incomplete that the principle of the mechanism cannot be clearly determined. In any case, it deals with a Cardan syspended horizon in which, however, the rotor axis is not vertical to the inner Cardan axis. In this manner they avoid the coincidence of rotor axis and external Cardan axis after a turn of 90 degrees around the inner Cardan axis; however, in this singular case the axes of the system still fall in a plane. The mechanism equipped with an alternating-current gyroscope weights about 2 kg and has external measurements of 126 x 189 x 132 mm.

The method of operation of another aerobatic horizon which is, however, presented only as a diagrammatic sketch, is easy to see through. In this case they have used a third Cardan ring in which the external Cardan axis of the otherwise normal horizon system is located. The additional Cardan ring is adjusted as usual and thus will only be free when the gyroscope housing has turned 70 degrees around the inner Cardan axis. The adjustment of the additional ring will be switched on again if the rotary angle β of the gyroscope housing leaves the range $70^\circ < \beta < 110^\circ$. In this manner the gyroscope will be given an additional degree of freedom in the region of the dangerous "clinch-position."

The section about the various horizons is concluded with a short description of three different power-assisted artificial horizons in which the gyroscope is only the sensitive element; the stabilizing forces, however, of assistance motors are applied. Three simple schematic sketches of such equipment (with 1,2 and 4 gyroscopes) are shown, but there is no indication whether mechanisms of this type have been built. The sketch of the arrangement with four gyroscopes deviates from the power-assisted artificial horizon outlined by Roitenberg in 1942 only to the extent that here the rotor axes are all vertical to the plane of the stabilized platform, while the original (Roitenberg) arrangement placed the gyroscopes so that the rotor axes were parallel to the platform.

Also, in the discussion of the gyroscopic course indicator, as in the discussion of horizons, after a short description of the main possibilities, a general error theory is brought forth which represents in a noteworthy and complete manner the errors (caused) by the rotation of the earth, displacement of the center of gravity,

axial friction, Cardan suspension and by acceleration forces in various flight positions.

The above mentioned gyroscopic course indicator, which was already comprehensively reported on page 45, is here described in detail as the first mechanism. Here they are dealing with a gyroscopic course indicator with a magnetic assistance in which the magnet needle serving as sensitive element is located directly over the gyroscope in the mechanism housing. It is also worth noting in this construction that the assistance of the gyroscope system around the inner Cardan axis does not occur simply vertically to the plane of the external Cardan frame, but rather, vertical to the direction of the apparent perpendicular which is indicated -- as in the pneumatic Sperry horizon -- by two small regulatory pendulums. D. A. Braslavskiy, M. G. Elkind and M. M. Katchkatchian are named as designers of this mechanism.

[The Russians] have sought to avoid the disadvantages of the pneumatic mechanism with direct magnetic assistance by the further development that first of all one assumes a separation between course detectors and gyroscopes, secondly, that the mechanism is electrically operated and finally, thirdly, an induction compass is used in place of a magnetic needle. In order to get the necessary assistance currents for the gyroscope, an additional two-step tube amplifier is installed between the induction transmitter and the gyroscope. The mechanism thus produced is illustrated in detail by construction sketches and photographs.

On the other hand, a "gyroscope-induction-compass," which was
(P.36)
already mentioned in Schlandin's book [redacted], is treated in a relatively brief manner. They are dealing here with an induction compass in which the three induction coils, which are reset at each 120°, are mounted on an artificial horizon in order thus to remain constantly in the horizontal plane.

The mechanical possibility for assistance which was applied by Alkan -- that is, a rotating sphere on the gyroscope housing -- is mentioned quite briefly.

At the conclusion of the section on gyroscopes equipment, a "three-gyroscope-central," which can assume the job of horizon and gyroscopic course indicator at the same time, is once again described in brief. In this they are dealing with a fusion of three normal monoaxial power stabilizations which consist of one gyroscope each and one (power) assistance motor for each axis. A magnet compass is provided as a measuring gauge for the course axis while liquid spirit levels are provided for the other two axes. The controls for the assistance motors around the two transverse axes are calculated in this case in a special coordinate converter from the indicator values of the spirit level. Also, in the section about automatic pilots the names of the most important Soviet researchers are mentioned. In this section we read: "The questions of the dynamic stability of the airplane are explained not only theoretically but experimentally in the fundamental works of V.P. Vetchinkin, V. S. Vedrov, V. S. Psychnov, L. V. Klimenko, I. V. Ostoslavskiy, G. S. Kalatschev, and others. ... A number of successful constructions of automatic pilots were designed by the Soviet engineers I. A. Timofeyev, A. A. Lusis, M. F. Sediskiy, V. Ye. Sorkin, and others, in which the products of foreign firms were considerably surpassed. The engineers Ye. F. Antinov, Ye. V. Olman, L. I. Semenov and others have played a large part in the recent development of the construction of automatic pilots in the USSR.

After the presentation of theory for automatic pilots, which for the purpose of this book was fully sufficient, several designs are then described more closely. In this it is worthwhile to note

that the automatic pilots described in the book (Page 37) are no longer mentioned at all. One could therefore assume that they have since been replaced by more recent designs. Also, the 3-axis automatic pilot PGAP (abbreviation for "pneumatic-hydraulic automatic pilot") which is next described in the book can again (be considered) as having already been made obsolete. It still has the principal structure which has been known since the old pneumatic Sperry 3-axis control. The horizon, however, had been somewhat redesigned.

[redacted]

Also the automatic pilot of EAP type (abbreviation for "electrical automatic pilot") which was next described, has apparently not been successful. It operates according to the same principle as the previously mentioned automatic pilot and has as gyroscope mechanism a horizon as well as a course indicator gyroscope. The rigid circuit is rigidly formed so that when unidirectional moments appear, certain residual errors will still remain.

The next described automatic pilot of type EAPB (abbreviation for "electrical automatic pilot <u>without</u> rigid return circuit") has been completely changed in the principle design and construction. One can recognize without difficulty that the German 3-axis control of Rechlin (Moeller) as well as the structural parts of IGW and Patin were the sources in the design of the control A telecourse indicator gyroscope assisted by a magnet needle serves as measuring transmitter for the vertical axis of plane and also, for each of the three axes an additional damping gyroscope which simultaneously dispenses with the rate of revolution and the rotary acceleration. On the inner Cardan axis of the horizon there is further mounted an additional acceleration gauge which dispenses with the horizontal component

of the airplane's acceleration and operates as an additional controlling entity for the longitudinal bearing. * The mixture of the individual measuring values comes about -- as in the Patin mechanism -- through highly receptive galvanometric systems with multiple input coils and potentiometer tapping for the output. The telecompass, as well as the horizon also, is used at the same time for the recording and for this purpose is connected with corresponding "repeaters." Data given for these automatic pilots is as follows:

Service altitude	12 km
Feed voltage	27 v ± 10%
Moment of steering engine	18 mkg
Maximum speed on drift bar of steering engine	70 mm/sec
Necessary power	500 w
Weight	75 kg
Admissible pitch angle	± 85°
Admissible banking angle	± 70°

* P.S. Besides the above-named measuring transmitters there is also a Pitot tube whose recording value is likewise drawn into the formation of the control values for the longitudinal control.

REVIEW OF RUSSIAN WORKS ON APPLIED MATHEMATICS, MECHANICS, AND GYROSCOPICS

G. V. Shchipanov, Giroskopicheskiyepribory slepogo poleta. Teoriya,, raschet i metody konstruirovaniya [Gyroscopic Devices for Blind Flying. Theory, Computation, and Construction Methods], State Publishing House for the Defense Industry, Moscow-Leningrad, 423 pages, 6,000 copies.

According to the preface by the author, this book may be regarded as a sequel and supplement to a book by the same author entitled, "Theory, Computation, and Construction Methods of Aeronautical Devices." This book, covering blind-flying gyroscopic devices, consists of two parts. The first part deals with the "Special Theory of the Pendulum and Gyroscopic Directional Indicator" and allegedly gives the theoretical fundamentals on which the computation and construction are based. The second part of the book entitled "Gyro Compass, Artificial Horizon, and Turn Indicator" shows how the general theory is applied to special devices, whereby the author limits himself to the three aforementioned gyroscopic devices. Not one word is said in the entire book about the directional gyro, although at the time of the book's publication such a finished and tested device was already available.

The author does not mention in his introduction -- as is the usual procedure in Russian books -- for what group of readers the book was written. Better books are available for the theorist, for instance "Applied Gyro Theory" by Bulgakov which appeared two years before this book, or the book written by Krylov and Krutkov on "General Gyro Theory" which is still older. The theory offered in this case is, despite the many superfluous formulas which fill lots of pages, full of gaps and incomplete, and in many cases simply misleading. The book can hardly be recommended for designers since the unnecessary multitude of formulas only causes confusion. You cannot expect the designer to struggle through more than four hundred pages of obscure calculations and to find out in the end that the solution of the problem he wants is not found in the book. One concludes therefore that this voluminous book is redundant and without value. It could even be mentioned as having a damaging effect on the reader since without hesitation too much use has been made of approximations in the calculations and many of the drawings and sketches lack the necessary accuracy. Some of them are not only quantitatively wrong but simply qualitatively untrue.

The first part of the book covering close to two hundred pages and treating of "Special Theory", gives long-winded explanations on general problems of the theoretical mechanics, which can be found much better, clearer, and more concise in textbooks on theoretical mechanics. The manner of word usage also is very misleading. For example, the author uses the expressions of precession and nutation generally for the two natural frequencies of systems with two degrees of freedom. At another place the same nomenclature is used for two components of one and the same oscillation. The reader is spared nothing when the systems of two degrees of freedom are discussed. He has to endure all possible combinations of return, damping, and coupling terms in the linearly established two differential equations of the second degree. After reading about one hundred pages of this talk one will discover that an engineer well acquainted with theoretical mechanics could have come to this conclusion after reading a few pages. Thus the author finally arrives at two systems each consisting of two coupled linear differential equations which

only differ from each other in the type of the return terms. In the first system indicated with an "S" (Sperry), the return forces are placed above the cross in the differential equation system while in the second system, indicated with an "A" (Anschüetz), the return forces for a coordinate also are used for this coordinate in the differential equation. Later the author discusses some intermediate forms of these systems of equations and indicates them with "SA".

An approximation method, originally developed by Bairstov and was widely and without hesitation used in the solution of equations of the fourth degree.

The theory of the gyprocompass as presented in the second part of the book does not give us anything new as compared to what had been written by Krylov and Krutkov or by Bulgakov. However, in spite of the wide scope, important parts of this theory, such as the pendulum error, are not discussed, and only briefly mentioned.

The theory of the acceleration-free synchronization (eighty-four minute principle) which is of fundamental importance, especially to the gyrocompass, is discussed in a biased manner. After this came the theory on gyroscopic horizons which is voluminous as well as incomplete. Again the author will tire his reader with unnecessary generalities of his research in which he also discusses the theory of systems which cannot be used in practice. Two devices are discussed in detail; the Sperry gyro horizon and the gyro horizon of Anschüetz and Co. While testing the two devices, the author ventures to predict that the Anschüetz gyro horizon will in the future displace the Sperry instrument especially if one thinks of the utilization of the gyro horizon in the automatic pilot. The seventeen years since the publication of the book have proved the opposite to be true.

During the discussion of the Sperry horizon it may be of interest to note that it was tried without result to make the dimensions of the Sperry horizon smaller, without decreasing its accuracy. It does not follow from the text, however, where and how these tests were made. During the discussion of the error theory of the Sperry horizon, one is startled to find that the maximum error approximates the angle at which the control pendulums clear the exhaust nozzles completely. This misleading result is no doubt caused by the fact that the error theory actually forms the basis for the behavior with accelerated rectilinear flight.

After enduring this theory of the gyro horizon one is not surprised at the statement that the gyro really is not used at all, and that what you need is to find the mechanism necessary to produce the terms in the differential equations. The author does not reveal, however, how he plans to do that without gyroscopes.

The theory of the turn-and-bank indicator, which actually forms the basis for the devices made by "Pioneer" and "Schilowski", is kept entirely within the framework of the gyro compass and horizon theories. For example, the computation of the springs for holding down the frame is given with all the details, as if there were no reference books for this type of computation, but not a word is said about the stabilizer.

In this chapter you also find the presumptuous assumption that the indicated method of computing not only can be used for Pioneer and Schilowski but also for any other constructive variation of bank-and-turn indicators, which may be conceived at all.

The last paragraph of the book, entitled "Construction Components, Sequence of the Computation, and Design of Gyroscopic Devices", is again noted

for the arrogant and unscrupulous manner in which the applied theory of gyroscopes is discussed in this book. Aside from the many things which were said before and are repeated again, a computation schedule is given for each of the devices under discussion from which the separate steps may be seen that have to be taken during the calculation. Since the formulas are given simultaneously with each step, actually you have an ideal "cookbook" in front of you with the help of which you can easily compute several compasses, horizons and bank-and-turn indicators on a weekly basis -- if the schedule were complete!

The schedule for the Sperry horizon contains, for instance, all data for the control pendulums as well as the air exhaust nozzles computed very accurately, but the only advice given for the computation of the rotor is: "Determine the dimensions of the rotor from the overall dimensions of the entire device". To determine the number of revolutions of the gyro the rule is simple: "Divide the obtained impulse by the moment inertia of the rotor!" The last of a total of twenty-five points of the plan to be followed in the computation of the Sperry horizon is called plainly and simply: "Control and stress calculations" in which the necessary formulas of course were not included.

To sum up the opinion of the reviewer: The book is written in an arrogant and obscure manner, hence it is without value. A designer can get much farther with the help of a textbook on theoretical mechanics and an engineer's manual.

N. I. Chistyakov, Elektricheskiye aviatsionnyye pribory [Electrical Instruments for Aviation State Publishing House for the Defense Industry, Moscow, 1950, 534 pages, 6,000 copies, price 18 rubles.

In the preface of the book the author emphasizes that several good books are available in the field of mechanical aeronautical devices. However, no suitable textbook was available on electrical aeronautical devices which could be used in school for the training of aeronautical engineers. The book supposedly fills this gap. It has officially been introduced as a textbook.

The preface begins with the sentence: "Our country is the country of an enormous air force. Soviet airplanes fly and will always fly higher, faster, and farther than all other planes in the world."

The introduction begins with the sentence: "Electrical devices originated in our country. The famous Russian scientist M. V. Lomonosov built the first apparatus to measure electricity about 200 years ago."

Nearly all chapters of the book start with similar sworn statements and in regard to gyroscopic devices there is no exception: "All basic principles and ways of application of the gyroscope have been worked out in the USSR by many Russian scientists and engineers such as A. N. Krylov, B. V. Bulgakov, Ye. B. Lewenthal, Ya. N. Roitenberg, G. A. Slomyanskiy, Ya. I. Soloviyev, G. O. Friedlander, S. S. Tichmenev.

This does not prevent the author from showing a few pages later mostly pictures of foreign gyroscopic devices, without mentioning naturally the land of their origin. Only about seventy pages of this bulky book are devoted to electrical aeronautical devices. The author confines himself to descriptions of the design and the operational characteristics of the most important gyroscopic devices. In only a few cases computations and diagrams of component parts of gyroscopic devices are given; for instance, on the various types of electric supporting devices, consisting of an indicator and a torque producing unit. The various possiblities of servomechanisms are also discussed; however, usually well-known foreign designs are quoted. The general constructions of bank-and-turn indicators, gyro horizons, force supported gyroscopic frames is

only briefly described, but much room is devoted to the discussion of the gyrocompass. The Russian designers followed in this case their own initiative as can be seen from the descriptions. Again you will find a description of the directional gyro controlled by a magnetic needle, in which the magnetic needle has been fastened directly above the gyroscope in the housing of the device. This arrangement is later abandoned in favor of a foreign design which provides a spacious separation between the gyroscope and the magnetic needle.

Independent from the monitoring by means of magnetic needles, much work has been done in the field of induction selsyns, which are capable of indicating the direction of the earth's magnetic field. Two of these devices, both of which also use a gyroscope, have been built and tested. The gyroscope in the "horizontally balanced induction compass" serves only as a horizon in order to establish a proper basis for the induction coils. A directional gyro is not present in this case. The reading of the induction selsyn is directly transferred to an indicator by means of an amplifier. In the case of the "gyro induction compass" we have a supported directional gyro the monitoring of which is provided by the induction selsyn. In this case the induction selsyn takes only the place of the magnet of the "remote reading compass." This gyro induction compass is described in great detail even with some constructional features included. Pictures of the finished apparatus are included. In order to be able to utilize the output currents of the induction selsyn for the support of the gyroscope, these currents are conducted across a two-stage tube amplifier located directly in the housing of the directional gyro. It may be concluded from other remarks that the design did not stand up too well for they were trying to obtain a higher degree of safety of operation through a change in construction. The construction of this device should be such that it can still be used even if the amplifier breaks down. For that reason they went back again to the use of a magnetic needle system as an indicator but this time its rotations were transmitted to the course axis of the gyroscope by means of a "magnesynsystem." If deviations are present a corresponding supporting current is applied to the internal cardanic axle. In case the support fails the magnesyn can be switched directly to the indicator.

A course indicator operating with an electron beam is also described. The deflection of an electron beam is used to indicate various courses. The directional gyro can be monitored by means of amplifiers. During the development of this device they planned to produce an inertialess indication of the direction of the earth's magnetic field. However, since the same goal was reached in a much simpler manner by the use of the inductive method, the work on the electron beam course indicator lost its importance and has been discontinued for some years.

A description of the "automatic pilot", discussed in several other books, is given in chapter XIX. The device can automatically plot the route of an airplane on a chart from data supplied by course and airspeed indicators. Accordingly it also contains a directional gyro in addition to an airspeed indicator. A disadvantage of the design is that changes in wind direction during flight cannot be allowed for, and that a certain sensitivity is present as a result of fluctuations in the voltage supply.

The bibliography at the end of the book lists a total of eighty-two publications which for the most part cover topics of a purely electrical nature. All worthwhile information related to gyroscopic devices has been included in the bibliography of the main report.

V. A. Pavlov, Aviatsionnyye giroskopicheskiye pribory [Aeronautical Gyroscopic Devices], State Publishing House for the Defense Industry, Moscow, 1954, 411 pages, price 12.85 rubles. (It is noteworthy that this publishing house no longer indicates the number of copies of the edition.)

This book may be considered the second edition of a book published in 1946, entitled: "Fundamentals of the Design of Gyroscopic Devices". It has been introduced as a textbook for the special field of "aeronautical devices" for advanced training in aeronautical schools. Apparently the author had given a course on gyroscopic devices for quite some time in such a school and finally published the material used in this course in book form in an amplified manner.

As compared to the first edition the number of pages of the book has almost doubled (411 as compared to the previous 223 pages); however, if the larger format is also considered, it has more than doubled. It may be noted that the price of the book has been lowered despite its greater size and that it is a considerably better publication. Through comparison of the tables of content it was determined that the increase in size actually can be traced to the fact that a description and the theory of special gyroscopic devices is given in a number of chapters (III to IX), which formerly were not included. The wider scope in other parts of the book can nearly without exception be explained by the wider and more detailed discussion of the theory -- as I am sorry to say! For the theory was already rather weak in the first edition, while part of the more practical sections are excellent. These practical sections, however, have been copied without much change.

The manner in which the theoretical fundamentals as well as the computation of some devices is done is typical of Russian textbooks. It is a decided "cookbook" type theory! Instead of discussing some important examples so as to clarify the methods of computation, every single case is again thoroughly calculated with all possible details. In other words a tiresome repetition is presented in all sections of the solutions of some differential equations with constant coefficients with sometimes small variations in initial conditions or in the single terms of the initial equations. It is difficult to conceive that all this material can be mastered within the scope of a course on aeronautical devices, as presented in this book.

It is obvious that this book is the work of a teacher of long standing, because a great number of rather good demonstration models are described and shown in pictures. The great number of exercises are evidence of an intensive instruction method.

The introduction contains some valuable references. The names of some designers are mentioned here who have distinguished themselves, especially in the development of gyroscopic devices. They are V. I. Kusnetsov, Ye. F. Antikov, S. F. Farmakoriskiy, and A. I. Markov; in another place in the book, D. A. Braslanskiy, M. M. Katschkatschian and M. G. Elkind, are mentioned as the designers of the directional gyro supported by a magnetic needle. Furthermore S. A. Nosdrovskiy is called the inventor of the force supported gyroscopic frame. In addition, the same theorists are mentioned who are already sufficiently known from other publications.

Chapters I and II present the general theoretical fundamentals. Especially the influence of friction on bearings as well as the effects of the earth's rotation are examined. The gimbal rings are now also considered in the derivation of the general gyro equations, apparently according to the example of Nikolai. All other calculations, however, are based on the simplified linearized gyro equations.

The only point of interest in chapter III, which covers simple, nonsupported directional gyros, is the statement about two migration curves which were recorded with two different devices. The larger had an average migration of 10°/hour with a rotor weight of 700 grams, while the smaller with a rotor weight of 172 grams had a migration of 25°/hour.

In chapter IV you learn that the supported directional gyroscope as developed in the USSR in which the correcting magnetic needle is installed directly above the rotor in the housing of the device, has been abandoned in favor of the "telecompass". The latter device, the design of which incorporates a separation between the gyroscope and the magnetic needle, has been described in detail with its various types of transmission. The Russian development appears in close support of previous German design. The "gyroscopic magnet", in which simply a magnetic needle is rigidly connected to a rotor housing, as proposed by Chochlov and appearing with a detailed calculation in a publication (number 29 of the bibliography), is mentioned by Pavlov as "interesting, but of impractical design."

Something new seems to be indicated by the possibility of keeping the directional gyro free from errors during certain aerobatic flight patterns. An arresting pin is installed in the gyro housing, which prevents the swinging through when rotating around the inside cardanic axis. Precession will cause the system to rotate rather rapidly around the outer axis until the inner ring is again released after a rotation of 180°.

Chapter V on the gyro compass is very detailed but of no importance. One is surprised to find it in this book at all, for it is specifically pointed out that the use of gyrocompasses in aircraft is not advisable because of their extensive weight and large course errors.

Chapter VI, dedicated to artificial horizons and verticals, included long descriptions and calculations for the many possible types of supports without showing or describing any definite devices. It may be of interest to point out here that the Soviets have picked up the original idea of Glitscher to obtain a compensation of error through the introduction of an artificial "drift to port". A diagram is shown in Figure 6.25 which looks exactly like a design by Glitscher. Whether such devices are actually being built cannot be deduced from the text.

Bank-and-turn indicators are discussed in Chapter VII. Actually it is a discussion of designs of German firms, some of which have been copied in the USSR. Something new in this chapter is the description of a bank and turn indicator, which lately in Russian literature is called "gyrotachometer", in which an increase in accuracy of indication is obtained by setting the reading always back to zero by means of shifting the zero point of the spring restrainer, which shift is then taken as a measure of the speed of rotation. It cannot be determined whether this device or any other gyroscopes for measuring velocity and acceleration described in this book have actually been built.

Chapter VIII mainly presents diagrams as well as some theory on a great variety of types of force supported gyro systems, also called inertia frames; however, no specific data on devices of this type are given.

Chapter IX contains a brief discussion on a position and angular velocity recorder for three components as developed by TsAGI, also on integrating and differentiating gyroscopic devices; finally a "gyro relay" and a "vector stabilizer" are mentioned of which the latter is used to determine the ground speed.

Chapters X up to XIV were taken from the first edition of the book with minor changes. The various component parts of gyroscopic devices such as rotors, bearings, supports, current transmission systems, and arresting equipment are discussed in these chapters.

The tables with rotor data taken from the first volume are here mainly

supplemented by the inclusion of smaller types of gyros. It is further found that the former German gyro types KA 4, KA 5, KA 7, as well as the LGW spherical gyro with a diameter of 30 mm (the so-called "mad walnut") are also included. One is of course somewhat surprised by the bold statement that this type gyro is an advanced development of one of the designs developed by the author (Pavlov). This "Pavlov gyro", of which even pictures are shown in an disassembled as well as assembled state appears to be very primitive; it consists of two halves of similar design, each provided with its own drive and coupled together with a pin. Each of the top-shaped halves has only one ball bearing, so that it is difficult to see how the system can operate sensibly.

This time smaller ball bearings have been considered in the chapter on supports and the tables have been supplemented accordingly. The latest results on the problem of friction in high-precision ball bearings (by Vieweg in Darmstadt) were evaluated, naturally without indicating the source!

The new edition also contains a small and incomplete sketch for an air-supported or liquid-supported gyroscopic device. After a poor description of only fourteen lines it says: "it should be pointed out that the type of support under discussion can only be used with gyroscopes having two degrees of freedom which remain stationary on the earth's surface. Despite a number of advantages of the described type of support, ball bearings are mainly used in aeronautical gyroscopic devices, because they have a longer life and also operate better in systems subjected to vibrations."

Contrary to the poor information on air supports, you find again, as in the first edition, detailed information on various types of oscillating supports. Based on information found in this book it may be assumed with a high degree of probability that thorough investigation has been carried out in the USSR in connection with this problem. Numerical data on the values of friction obtained with various types of bearings show that with oscillating supports they still cannot approach the values as obtained with prismatic supports.

In the chapter on rotor bearings the Anschuetz gyroscope bearing is discussed in detail.

Much practical material was assembled during the research on greatly different supporting devices. But also in this case preferably foreign designs were described. In a discussion on the support of the directional gyro by means of the earth's magnetic field, it was noticed that in addition to the established methods with the aid of magnetic needles or the induction compass, a device was described which operates with an electron beam. This device, developed by L. A. Gontscharskiy, A. P. Moltschanov, and V. K. Svorykin, utilizes the deflection of the beam of electrons caused by the earth's magnetic field to generate a supporting current.

The information and pictures on the problem of pneumatic support of the inside gimbal rings for the directional gyro are proof of the intensive work being done in this field. Measurements are made of the air pressure inside the gyro housing to determine the most favorable type of air conduit for the support. An electric support is recommended for larger gyros which will make it easier to obtain greater supporting moments.

The "Bulgakov Method" is used to determine the effect of supports with the gyro horizon.

The two chapters on power transmissions and arresting devices have been

enlarged somewhat, but most of the descriptions discuss German designs.

Chapter XV entitled "How to Determine the Main Characteristics of Gyroscopic Devices" is a new chapter. After a brief description of various devices (three German designs as well as the three-component recorder developed by TsAGI), examples are given of calculations for all important gyroscopic devices and illustrated by means of numerical examples. It is possible that the teachers in the USSR have experienced such poor results with their teaching methods that by writing this type of "cookbook" they hope it may improve. You can find here all formulas if you want to compute "classic" gyroscopic devices but in all other cases the book does not help. The warning directed by the author at the end of the chapter to the students that they cannot always follow this schedule to the letter probably will make the "cookbook engineers" more helpless.

Summarizing, it may be said that this new edition is very valuable, since plenty of material has been compiled in it. Unfortunately the important practical sections have hardly been supplemented while it would have been a pleasure to give up the insignificant theory.

V. V. Rumyantsev, "The Stability of the Spiral Motion of a Rigid Body in a Liquid under Conditions Specified by S. A. Chaplygin", Prikladnaya matematika i mekhanika [Applied Mathematics and Mechanics], Vol XIX, 1955, pages 229-230.

Chaplygin established the equations for the general motion of a rigid body in an infinitely expanded, ideal, incompressible liquid, and proved that in a special case four integrals of these equations can be estimated so that the problem can be reduced to a quadrature. Rumyantsev now indicates a special solution of the Chaplygin equations which corresponds to the case of a constant spiral motion of the body in the liquid. The stability of this spiral motion may now be found by examining the disturbed motion. The author forms a Liapunov function from three special integrals according to the example of Chaplygin from which then the stability conditions may be derived according to the well known requirements of definability. In the special case of a nonprogressive motion they are changed into the well-known stability conditions for the case as examined by S. V. Kovalevskiy.

P. V. Kharlamov, "An Integral Case of the Equations of Motion of the Heavy Rigid Body in a Liquid", Prikladnaya matematika i mekhanika [Applied Mathematics and Mechanics], Vol XIX, 1955, pages 231-233.

In connection with the research done by S. A. Chaplygin, a new case is presented in which the equation of motion for a rigid body located in an infinitely expanded ideal incompressible liquid can be integrated. In this particular case the center of gravity of the rigid body does not coincide with the center of gravity of the liquid mass displaced by it. Moreover, we are dealing here with a generalization of the well-known case of Lagrange, for which now a certain motion of propagation is allowed. The author succeeds in finding the solution of the angle of nutation and precession in the form of elliptic integrals. Then the author examines the stability of the motion found in this manner for a further simplified special case of this solution while determining a Liapunov function. The postulate of the definability of this function will give us the stability conditions we are looking for.

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